

# Characterization of Al-15Ni-1Mg with Reinforcement of Al<sub>2</sub>O<sub>3</sub> and Flyash using Powder Metallurgy

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**Abstract** — Now a day's powder metallurgy became more popular in automotive industry. Metal matrix composites are widely used than metals alone because of the strength point of view. The properties of the aluminium based metal matrix composites are better than pure aluminium. In this project, the study of the effect of mechanical and metallurgical properties of Al-15Ni-1Mg composite reinforced with Al<sub>2</sub>O<sub>3</sub> and fly ash is considered. The ternary blends of Al-15Ni-1Mg is prepared, with reinforcement of ceramic powder of Al<sub>2</sub>O<sub>3</sub> and fly ash for different compositions of 0, 2.5, 5, 7.5, 10, 12.5, 15% through compacting and sintering is carried out in a tubular furnace for about 45 minutes at 580<sup>o</sup>C. The variation of mechanical and metallurgical properties of the metal matrix composites like green strength, compressive strength, hardness, micro structure and SEM analysis with reinforcements of Al<sub>2</sub>O<sub>3</sub> and fly ash are observed.

**Keywords** — Aluminium, Nickel, Magnesium, Aluminium Oxide, Fly ash, Powder Metallurgy.

## I. INTRODUCTION

For the past 40 years, materials design has shifted emphasis on pursuing light weight, environment friendly, low cost, quality, and better performance materials. Metal Matrix composites exhibits better mechanical, physical and metallurgical properties at various proportions with different reinforcement leads to its growing applications (Kaczmar et al., 2000; Rohatgi et al., 1992; Chawla, 1992). However, the low ductility property and low-transverse creep resistance developed due to the hard particulate reinforcement is the major drawback that limits the usage in structural component applications. A substantial research effort has been directed towards developing an improved understanding of their potential and limitations invoking principles of physical metallurgy, stress analysis, processing sciences and applications.

I.A. MacAskill et. al(2006) discussed the effect of reinforcement of silicon on the sintering process, metallurgical and mechanical properties of experimental Al-Ni-Mg PM alloy. Study of advancing through binary (Al-Mg), ternary (Al-Mg-Si and Al-Ni-Mg) and quaternary (Al-Ni-Mg-Si) systems was adopted. Intermetallic defects in Al<sub>3</sub>Ni is detected at minimum level. In addition, silicon significantly changed the morphology of Al<sub>3</sub>Ni in alloys of low nickel content.

S.F. Moustafa et.al(2001) Copper matrix reinforced with either Ni-coated or uncoated SiC and Al<sub>2</sub>O<sub>3</sub> particulate composites were made by means of the powder metallurgy route. The reinforcement particles of SiC and Al<sub>2</sub>O<sub>3</sub> were coated with a thin layer of nickel by electroless method. SiC or Al<sub>2</sub>O<sub>3</sub> reinforcement particle in the copper base metal is considered, with 20 wt%, at a stirring speed of 360 rpm for a period of 10 min. Each mixture of the investigated powders was cold compacted at 600 MPa, and sintered at 900 BC, in hydrogen atmosphere. Micrographs of Ni-coated particles of SiC and Al<sub>2</sub>O<sub>3</sub>, and the microstructure of the sintered composites are also provided.

## II. MATERIALS AND METHODS

### A. Selection of Materials

Base Material - Aluminium (fine powder), Magnesium, Nickel



**Fig.1.**Aluminium, Magnesium and Nickel powders

Reinforcement – Al<sub>2</sub>O<sub>3</sub>, Fly Ash



**Fig.2.** Al<sub>2</sub>O<sub>3</sub>, Fly Ash

*Table I. Chemical Composition of Al 6061*

Element	Mg	Si	Fe	Cu	Ti
Weight %	0.92	0.76	0.28	0.22	0.10
Cr	Zn	Mn	Be	V	
0.07	0.04	0.03	0.003	0.01	

### **B. Experimental work**

Initially weighing of materials with particular compositions using electronic weighing machine is done. And place that non-mixing materials into a jar that is without moisture and fasten it very tightly without entering the atmosphere air into it. Place the jar in the container. Once the container bolted tightly fasten it on the lathe machine jaws. Set the lathe machine in back gear and rotate the container for one hour as like five minutes clockwise and five minutes anti clockwise. Repeat the same procedure for one hour. After proper mixing of material in the lathe remove the jar from the container and pour powder into the conical flask. The conical flask closed with a rubber cork with hole for avoiding it from atmosphere. A small tube passes through cork hole. The powder is poured via small tube to the test tube. The weight of the sample taken into the test tube is 1.5gms.

Before applying the pressure on the powder form of the material, the place where they keep to applying the pressure are guides. These guides are clean with silicone spray. This spray is very useful while removing the final specimen from the guide and also helpful in removing the scales that formed inside the guide. The material in the test tube is poured into the guide, the bottom part of the guide containing a tip. The tip avoids the material leakage from the bottom part of the guide. After that a follower is used to close the other part of the guide by inserting it into the guide. The guide is again inserted into compression block. After that place it on the saddle of Compression testing machine.

After placing the compression block with guide and follower on the saddle of compression testing machine, the pressure was applied on the head of the follower carefully. Sometimes there is a chances of failure of follower head and possible chances of bending of the follower. After reaching the certain pressure first stop the applying of the pressure and remove the guide and follower from the compression block slowly and place it again in the ejection block. After that again applied the pressure until the specimen in guide falls on the table of compression testing machine and the follower gives sudden jerk at that time and we can hear a noise. And again repeat the same procedure for other composites for different pressures. After the final specimen emerges from the work, taken it carefully and place it in the small plastic cover for avoiding damage to the specimen. The final specimens are shown in fig. 3. After the making of total specimens completed, taken them to finding out the length, diameter and on the digital micrometer.



Fig.3. Final Specimens

Table II. Final specimens with different compositions weight percentages of  $Al_2O_3$ 

S.No	Al	Ni	Mg	$Al_2O_3$
1	84	15	1	0
2	81.5	15	1	2.5
3	79	15	1	5
4	76.5	15	1	7.5
5	74	15	1	10
6	71.5	15	1	12.5
7	69	15	1	15

Table III. Final specimens with different compositions weight percentages of Flyash

S.No	Al	Ni	Mg	Flyash
1	84	15	1	0
2	81.5	15	1	2.5
3	79	15	1	5
4	76.5	15	1	7.5
5	74	15	1	10
6	71.5	15	1	12.5
7	69	15	1	15

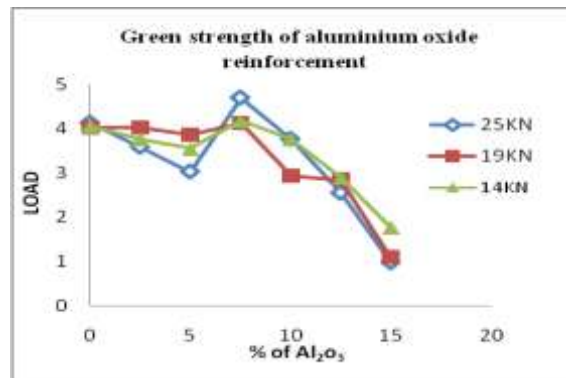
### III. RESULTS AND DISCUSSION

#### i. Green Strength of Aluminium Oxide doped specimens

The effect of compacting pressure and  $Al_2O_3$  content on the Green strength in fig 4.5& 4.6 respective

Table IV. Green Strength of  $Al_2O_3$  doped specimens

Percentage of $Al_2O_3$	Compaction Pressure		
	250MPa	350MPa	450MPa
0	4.0121	4.125	4.435
2.5	4.324	4.156	4.465
5	3.245	4.012	3.432
7.5	4.943	4.675	4.1775
10	2.312	2.876	2.402
12.5	1.5003	1.675	2.035
15	2.0043	2.024	2.021



**Fig.3.1 Effect of Compaction Pressure and Al<sub>2</sub>O<sub>3</sub> content on green strength**

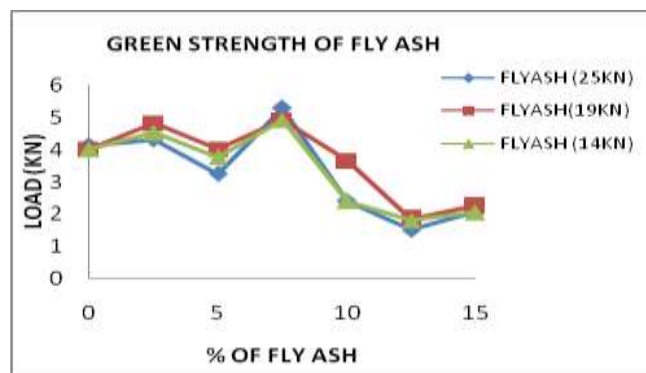
The Green strength is high at 7.5% of Al<sub>2</sub>O<sub>3</sub> for compacting pressure of 450Mpa and maximum of 4.1775KN. It can be observed in the fig 4.1. It is observed that the Green strength decreases with increasing in Al<sub>2</sub>O<sub>3</sub> content.

*ii. Green Strength of Fly Ash doped Specimens*

The Tensile test conducted on the Specimen by using Tensometer given the following results

*Table V. Green Strength of Fly Ash doped specimens*

Percentage of fly ash	Compaction Pressure		
	250MPa	350MPa	450MPa
0	4.0125	4.215	4.128
2.5	4.525	4.825	4.324
5	3.765	4.012	3.258
7.5	4.925	4.825	5.2959
10	2.412	3.655	2.412
12.5	1.5103	1.852	1.812
15	2.0595	2.254	2.059



**Fig.3.2 Effect of Compaction Pressure and Fly Ash content on green strength**

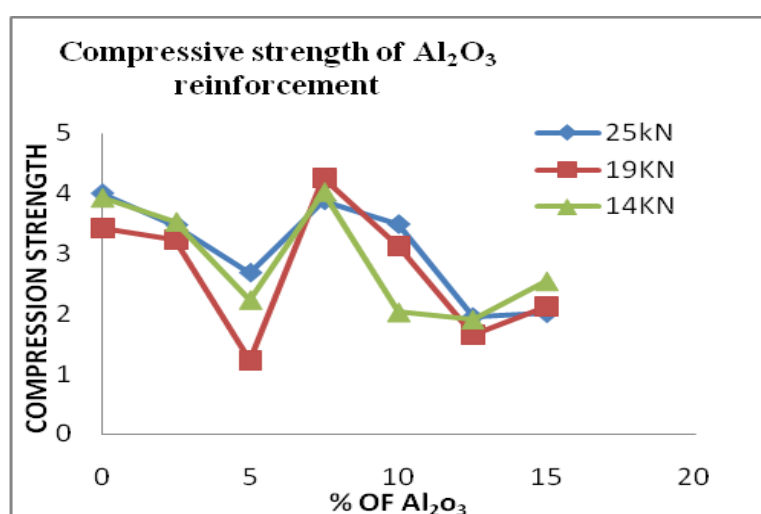
The Green strength is high at 7.5% of FA for compacting pressure of 450Mpa and maximum of 5.2959KN. It can be observed in the fig 4.2. It is observed that the Green strength decreases with increasing in FA content.

*iii. Compressive Strength of Aluminium Oxide doped specimens*

For ductile materials, compressive strength is generally considered corresponding to 20% of its maximum deformation. i.e. 20% of the specimen length.

Table VI. Compressive strength of specimens

Specimen No	Compaction pressure (MPa)	20% deformation	20% Compressive strength, N	Peak load value
1	250	1.878	4.0522	4.253
2	350	1.722	4.0233	4.023
3	450	1.892	4.128	4.132
4	250	1.878	3.765	3.765
5	350	1.922	4.0233	4.023
6	450	1.792	3.5894	3.589
7	250	2.14	3.546	2.638
8	350	1.892	3.864	3.864
9	450	1.988	3.0304	3.589
10	250	2.06	4.1774	4.177
11	350	2.234	4.12877	4.128
12	450	1.886	4.697	3.030
13	250	2.032	3.7659	3.765
14	350	2.158	2.9323	2.932
15	450	1.808	3.7659	4.697
16	250	1.762	2.899	2.889
17	350	1.829	2.8544	2.854
18	450	1.025	2.5498	2.549
19	250	1.589	1.768	1.768
20	350	2.013	1.0875	1.087
21	450	1.035	0.9817	0.980

Fig.3.3 Effect of Compaction pressure and Al<sub>2</sub>O<sub>3</sub> Content on compressive strength

The compressive strength is maximum of 4.12877kN at a 7.5% of Al<sub>2</sub>O<sub>3</sub> at the compaction pressure of 350 MPa

The green strength is increased with the increase in compaction pressure. It also tells about the peak load and break load. The peak load tells about the maximum load that can be applied on the specimen before it starts to breaking. The break load tells about the load at which the specimen is completely breaks.

*iv. Compressive Strength of Fly Ash doped specimens*

For ductile materials, compressive strength is generally considered corresponding to 20% of its maximum deformation. i.e. 20% of the specimen length.

Table VII. compressive strength of specimens

Specimen No	Compaction pressure (MPa)	20% deformation	20% Compressive strength, N	Peak load value
1	250	1.878	4.257	4.257
2	350	1.722	4.525	4.525
3	450	1.892	4.128	4.128
4	250	1.878	4.525	4.525
5	350	1.922	4.852	4.852
6	450	1.792	4.324	4.324
7	250	2.14	3.825	3.825
8	350	1.892	4.126	4.126
9	450	1.988	3.255	3.255
10	250	2.06	4.865	4.865
11	350	2.234	4.765	4.765
12	450	1.886	5.295	5.295
13	250	2.032	2.456	2.456
14	350	2.158	1.695	1.695
15	450	1.808	2.4125	2.4125
16	250	1.762	1.512	1.512
17	350	1.829	1.852	1.852
18	450	1.025	1.510	1.510
19	250	1.589	2.789	2.789
20	350	2.013	2.211	2.211
21	450	1.035	2.059	2.059

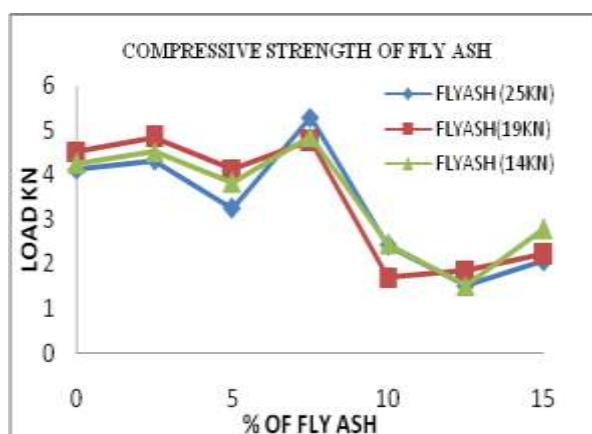


Fig.3.4 Effect of Compaction Pressure and Fly Ash content on compressive strength

The compressive strength is maximum of 5.2959KN at a 7.5% of Fly ash at the compaction pressure of 450 MPa.

The green strength is increased with the increase in compaction pressure. It also tells about the peak load and break load. The peak load tells about the maximum load that can be applied on the specimen before it starts to breaking. The break load tells about the load at which the specimen is completely breaks.

v. **Hardness of Metal Matrix Composite with Aluminium Oxide doped specimens**

Table VIII. Hardness of  $Al_2O_3$  doped specimens

Specimen No	Compacting pressure(MPa)	Hardness (HRC)
3	250	93.25
5	350	114
9	450	99.5
12	250	71
14	350	78
17	450	116
19	250	88.5
22	350	90.5
25	450	82.5
29	250	119.5
32	350	88.5
35	450	77.5
39	250	88
40	350	80.5
43	450	73
46	250	99
49	350	83
51	450	80
53	250	69
56	350	70
59	450	71

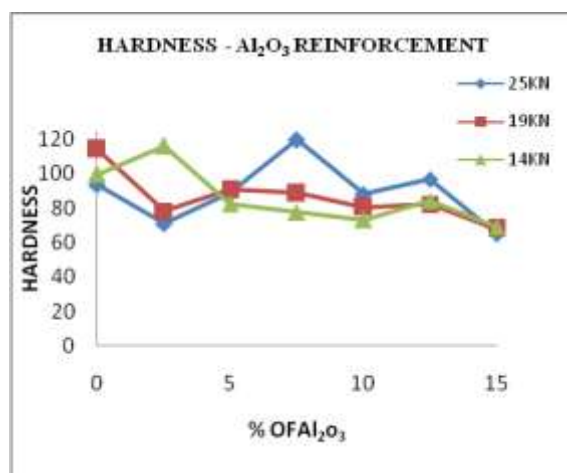


Fig.3.4 Effect of Compaction pressure and % of  $Al_2O_3$  on Hardness

The Hardness increases with increase in % of reinforcement and is maximum of 119.5HRC at the 7.5% of  $Al_2O_3$  with compaction pressure of 250Mpa.

vi. *Hardness of Metal Matrix Composite with Fly Ash doped specimens*

Table IX. Hardness of Fly Ash doped specimens

Specimen No	Compacting pressure(MPa)	Hardness(HRC)
3	250	93.25
5	350	114
9	450	99.5
12	250	122
14	350	117
17	450	118
19	250	108
22	350	119.5
25	450	98.75
29	250	78.5
32	350	96
35	450	78.75
39	250	79
40	350	96.5
43	450	97
46	250	96
49	350	84
51	450	75
53	250	61
56	350	65
59	450	70.5

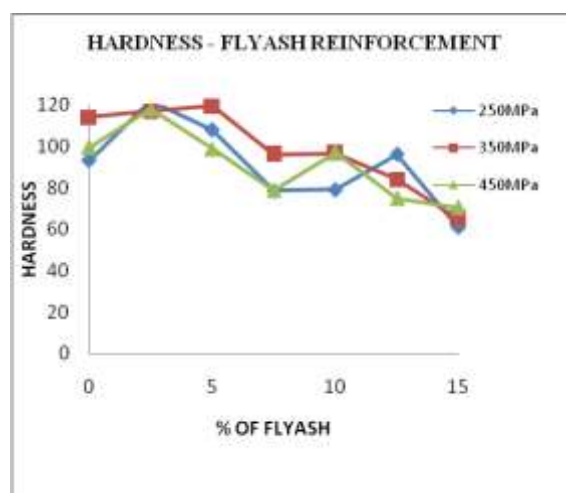
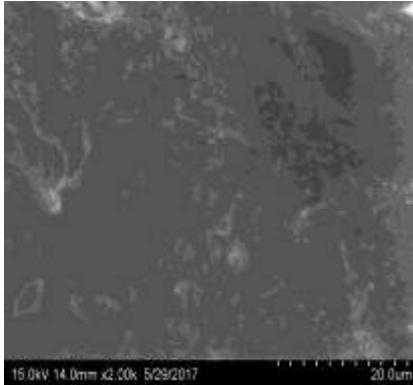


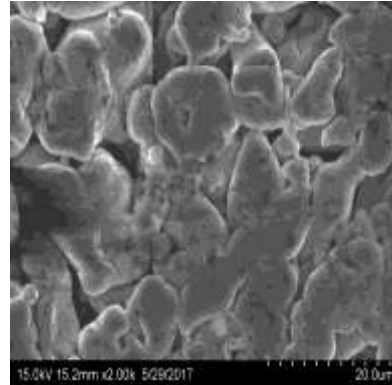
Fig.3.5 Effect of Compaction Pressure and Fly Ash content on hardness

The Hardness increases with increase in % of reinforcement and is maximum of 119.5HRC at the 7.5% of FA with compaction pressure of 350MPa.

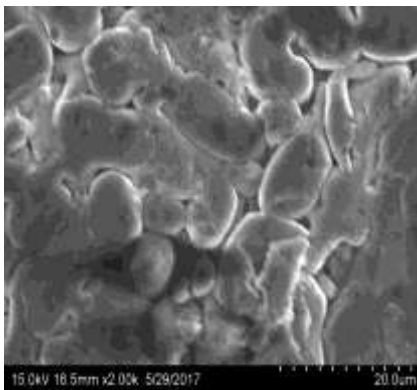
**vii. SEM analysis of  $Al_2O_3$  doped specimens**



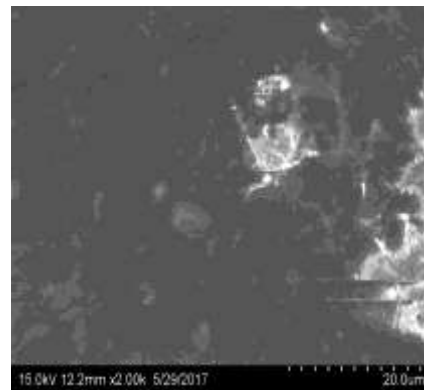
**Fig.3.6 SEM image of 84%Al-15%Ni-1%Mg – 0% $Al_2O_3$**



**Fig.3.7 SEM image of 81.5%Al-15%Ni-1%Mg – 5% $Al_2O_3$**

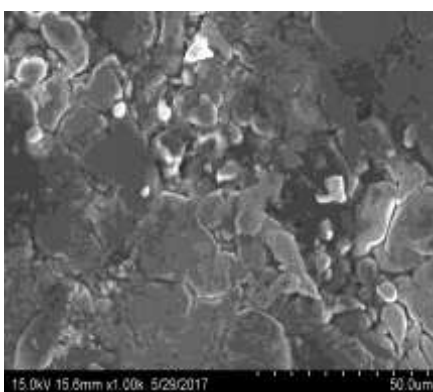


**Fig.3.8 SEM image of 79%Al-15%Ni-1%Mg – 10% $Al_2O_3$**

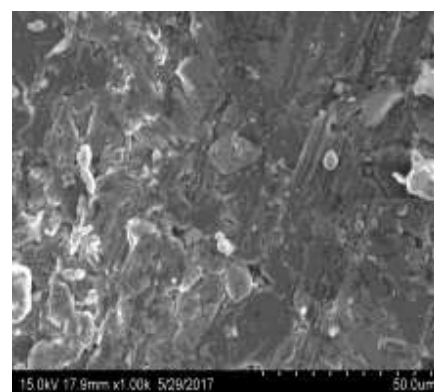


**Fig.3.8 SEM image of 76.5%Al-15%Ni-1%Mg – 15% $Al_2O_3$**

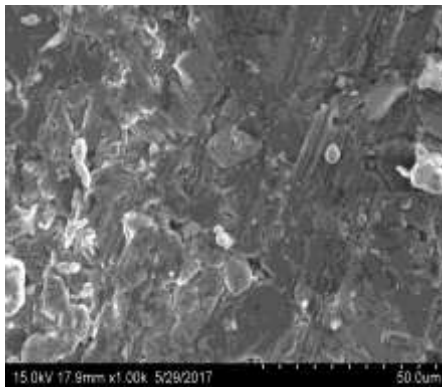
**viii. SEM analysis of Fly Ash doped specimens**



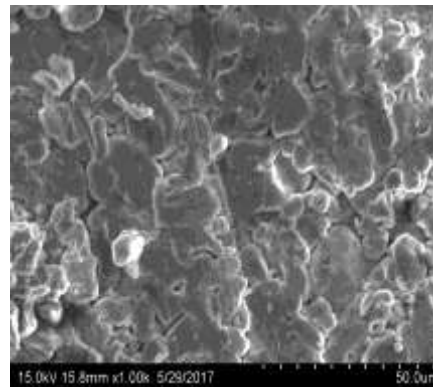
**Fig.3.9 SEM image of 84%Al-15%Ni-1%Mg – 0%Flyash**



**Fig.3.7 SEM image of 81.5%Al-15%Ni-1%Mg – 5% Flyash**



**Fig.3.8 SEM image of 79%Al-15%Ni-1%Mg – 10%Al<sub>2</sub>O<sub>3</sub>**



**Fig.3.8 SEM image of 76.5%Al-15%Ni-1%Mg – 15%Flyash**

Surface morphology of Al<sub>2</sub>O<sub>3</sub> doped samples in Al-15Ni-1Mg composition is shown in figure 4.7. The SEM images of Al<sub>2</sub>O<sub>3</sub> doped ceramic exhibit larger grains than those observed in the Al<sub>2</sub>O<sub>3</sub> free sample. The SEM images show a reasonably homogeneous distribution of the grains in ceramic sample. From the SEM pictures, with an increase of Al<sub>2</sub>O<sub>3</sub> content gradually increase in the volume fraction of grains in the samples is observed up to 10 weight % beyond this concentration the grain size of these crystallites is found to decrease, which in turn indicates 10% is optimum reinforcement for preparation of metal matrix composites.

#### IV. CONCLUSIONS

The conclusions drawn from the present work are:

1. Aluminium oxide and Fly ash up to 15% of weight can be successfully reinforced to Al-15Ni-1Mg by powder metallurgy to produce metal matrix composites.
2. The Hardness increases with increase in percentage of reinforcement and is maximum of 119.5HRC at the 7.5% of Al<sub>2</sub>O<sub>3</sub> with compaction pressure of 450Mpa and is maximum of 122HRC at the 7.5% of Fly ash with compaction pressure of 250Mpa .
3. The compressive strength is maximum of 4.322KN at a 7.5% of Al<sub>2</sub>O<sub>3</sub> at the compaction pressure of 350 MPa and is maximum of 5.2959KN at a 7.5% of Fly ash at the compaction pressure of 450 MPa
4. The Maximum green strength of 4.1775KN is at 7.5% of Al<sub>2</sub>O<sub>3</sub> for compacting pressure of 450Mpa and maximum green strength of is 4.775KN is at 7.5% of Fly ash for compacting pressure of 450Mpa. It is also observed that the green strength decreases with increasing in Al<sub>2</sub>O<sub>3</sub> and fly ash content.
5. The microstructure of the specimens are finding out on the metallurgical microscope. The micrograph reveals that the aluminium oxide and Fly ash is evenly mixed with Al-15Ni-1Mg.
6. From SEM analysis, with an increase of Al<sub>2</sub>O<sub>3</sub> and fly ash content gradually increase in the volume fraction of grains in the samples is observed up to 10 weight % beyond this concentration the grain size of the crystallites is found to decrease, which in turn indicates 10% is optimum reinforcement for preparation of metal matrix composites.

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## REFERENCES

- [1] S. A. Arendt and S. J. Bailey (eds.): 'Annual book of ASTM standards 2005, section two – nonferrous metal products', Vol. 2.05, 312–314; 2005, West Conshohocken, PA, ASTM International.
- [2] E. A. Starke, Jr: in 'Alloying', (ed. J. L. Walter et al.), 165–197; 1998, Metals Park, OH, ASM International.
- [3] M. J. Couper, J. W. Luster and M. Thumann: Powder Metall. Int., 1991, 23, 7–8.
- [4] N. A. Belov, V. S. Zolotarevskij and E. E. Tagiev: Izv. AN SSSR: Metall., 1992, 1, 146–151.
- [5] D. J. Chellman and T. D. Bayha: Proc. PM World Cong., San Francisco, CA, USA, June 1992, MPIF, Part 7, 257–270.
- [6] K. Vedula and J. R. Stephens: Proc. Int. PM Conf., Vol. 2, 1313–1316; 1986, Duesseldorf, EPMF.
- [7] E. W. Blumer: Proc. Conf. on 'Low density, high temperature PM alloys', Detroit, MI, USA, October 1990, TSM, 241–250.
- [8] Y. L. Wu, F. H. Froes, C. G. Li and J. Liu: Proc. 1997 TMS Annual Meet., Orlando, FL, USA, February 1997, TMS, 73–81.
- [9] R. M. Gomes, T. Sato, H. Tezuka and A. Kamio: Mater. Sci. Forum, 1996, 217–222, 789–794.
- [10] P. Yu, C. Deng, N. Ma and D. H. L. Ng: J. Mater. Res., 2004, 19, 1187–1196.
- [11] Hui-zhong LI, Ruo-mei LIU, Xiao-peng LIANG, Effect of pre-deformation on microstructures and mechanical properties of high purity Al–Cu–Mg alloy, accepted 11 April 2016, 1482–1490.
- [12] Muhammad Rashad, Fusheng Pan, Muhammad Asif, Room temperature mechanical properties of Mg–Cu–Al alloys synthesized using powder metallurgy method, Accepted 21 July 2015, Materials Science & Engineering A644(2015)129–136.
- [13] F. ERDEMIR, A. CANAKCI, T. VAROL, microstructural characterization and mechanical properties of functionally graded Al<sub>2</sub>O<sub>3</sub>/SiC composites prepared by powder metallurgy techniques, accepted 6 May 2015, 10.1016/s1003-6326(15) 63996-6.
- [14] J. Corrochano, J.C. Walker, M. Lieblich, W.M. Rainforth, Dry sliding wear behaviour of powder metallurgy Al–Mg–Si alloy–MoSi<sub>2</sub> composites and the relationship with the microstructure, Accepted 28 January 2011, Wear 270 (2011) 658–665.
- [15] Xiaofan Du, Tong Gao, Guiliang Liu, Xiangfa Liu, In situ synthesizing SiC particles and its strengthening effect on an Al–Si–Cu–Ni–Mg piston alloy, Accepted 17 October 2016, Elsevier, 695 (2017).
- [16] A. Wagih, Mechanical properties of Al–Mg/Al<sub>2</sub>O<sub>3</sub> nanocomposite powder produced by mechanical alloying, Accepted 6 October 2014, 0921-8831.
- [17] K. Soorya Prakash, P.M. Gopal, D. Anburuse, V. Kavimani, Mechanical, corrosion and wear characteristics of powder metallurgy processed Ti–6Al–4V/B<sub>4</sub>C metal matrix composites, Accepted 2 November 2016, Ain Shams Engineering Journal xxx (2016) xxx–xxx.
- [18] Aykut Canakci, Temel Varol, Microstructure and properties of AA7075/Al–SiC composites fabricated using powder metallurgy and hot pressing, Accepted 13 August 2014, Powder Technology 268 (2014) 72–79.
- [19] M. Jayaram, microstructure analysis of aluminium–boron carbide with addition of fly ash by using powder metallurgy technique, ISSN: 2455-2666, IRJLTET, Vol.2 No.2 Mar/Apr 2015.
- [20] Anil Kumar Bodukuri, Prof. K. Eswaraiah, Katla Rajendar and V. Sampath, Fabrication of Al–SiC–B<sub>4</sub>C Metal Matrix Composite by Powder Metallurgy Technique and Evaluating Mechanical Properties, 9-4-2016, S2213-0209(16)30120-3.