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Heat Treatment of Composites Fabricated by Powder Metallurgy

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ABSTRACT---In recent years Al2024 alloy had increasing applications in all the areas due to its good formability, excellent properties and etc. By using nano size B4C as size and graphite as reinforcements the fabrication process are done by Powder metallurgy process with overall 12 compositions primary and secondary specimens. Nano B4C are used as reinforcements from 3-15% with step of 3% as primary specimen and with addition of graphite of 3% in every reinforcements same manufactured. All specimens are manufactured by powder metallurgy technique and had a wide application. Hardness values are taken and each specimen is subjected to aging process. In aging process are subjected to 495°C and soaking for 2 to 10 hours. The cooling process can done by in three medium water. In each case hardness values are taken with micro Vickers tests. All results are taken shows that increase in hardness with aging process. FESEM analysis is conducted to know the microstructure of composites.

Keywords: Powder metallurgy technique; Micro hardness; Micro structure; SEM analysis; Non hybrid composite and hybrid composite.

I. INTRODUCTION

Aluminium alloys has low specific weight, high strength and excellent corrosive resistance had many applications in aerospace industries. For the above reasonssteelisreplacedinalmostallindustries for that purpose aluminium metal matrix has wide range applications. The various reinforcements that have been tried out to develop AMCs are graphite, silicon carbide, titanium carbide, tungsten, boron, Al O, flyash,Zr,Si3N4,TiB2. Theconventionalaluminiumbased composites possessonlyonetypeofreinforcements and therewasmorethan one reinforcements is used in hybrid composites. Addition of Gr particulates facilitates easy machining and results in reduced wear of Al–GrcompositescomparedtoAlalloy[1].Duetopropertiesincludingspecificstrength, specificstiffness, wearresistance,excellentcorrosion resistance and high elastic modulus Aluminium based Metal Matrix Composites (AMMC's) have been attracting a lot of attention in the fields of automotive, aerospace engineering and structural applications [2-4]. The composites have been fabricated by many manufacturing processes. In general, most metal matrix composites are produced by casting and powder metallurgy techniques [5]. Powder metallurgy techniques had limitations of size and shape of manufacturingand having a great advantage of simple and economical for large production rate [6]. The limitations in powder metallurgy process are non-uniform distributions of reinforcements particles, non-wet ability and incomplete adhesion and some casting defects are occurs [7,8]. In the mechanical properties of view MMC reinforcement had vital role intype,sizeofparticlesinthesizepointviewasthesizedecrease from micron to Nano there is as tremendous increase in the properties of composite. Amongallaluminiumalloys seriesAl2024hadapplicationin aerospace structure, rivets, hydraulic vales. B4C occupies next placeof the diamond in the hardness criteria. Graphite improves its machining properties of component. By the combinations of all mechanical propertieshadtobeimprovesthebasematerial.Theproductionand mixing of compositions of composite and hybrid composite are based on rule of mixture. All the defects that are occurred as the casting defects are minimised are avoided effectively by the pre heating and heattreatmentprocess[9].Secondaryprocessofallmaterialsimproves mechanical propertiesthatcanbeeithercoldworkingorhotworking operations[10,11]. Itwasexperimentallyprovedthatthereisanincrease in all the properties like stiffness strength wear resistance corrosive resistance and exhibit excellent mechanical strength compared to initial manufacturing process like casting powder metallurgy and sonic casting methodology [12]. Among all the available secondary processing techniques, aging is the most preferred because it can offer large plastic deformation without the failure of formed parts [13]. Some researchers have concluded that mechanically deformed and heat treated composites yields the maximum improvement in wear resistanceascomparedwiththe'as-cast'composite[14].

Nanosize to the Al2024 alloy matrix [15,16]. Heat treatment also improves the properties by grain size modifications. The grain size modifications are depends on the type of cooling. Cooling can be broad classified as the rapid cooling and slow cooling. In the former case i.e, rapid cooling process the biggest size of grains splits into small size grains that becomes hardness has more than that of initial hardness. By the slow cooling process small size particles small size grains will became bigsizeparticlesthatwillbeleadasthehardnesslessthanthatofinitial hardness.

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Besides the advantage of rapid cooling hardness there will be disadvantage of outer hardness is higher than lower harness that will lead saviour failure of operations. For the purpose of making the composite homogeneous though its sections is done by aging process. By the classification are can be done by maintaining of constant temperature for few hours.The experimental procedures are done by the two stage operations, in the first stage at high temperature quenching of material and second stage there will be maintaining of temperature for few hours for uniform graingrowthofmaterialparticles.

II MATERIALS

Powder metallurgy technique was used here because of its various advantages like less time simple fabricating technique, less cost of production, simple technique. Here the fabrication was carried out by two stages of Non-hybrid composites and hybrid composites. In the both types Al2024 was taken as the base material (matrix material), B4C and Graphite was taken as the reinforcement material. Al2024 was taken in 50 µm, Graphite was taken 100 µm, and B4C was taken in form of Nano size of 100 nm and all those materials was received from Nilesh Chand Material Suppliers, Pune. Compositions of Al2024 were shown in the Table1. The density ofthesepowdersandsizeofthesepowdersare shown in Table 2 and Figure1.

III MEASUREMENTS

The preparation of composites was started by measuring the powderwhichcoulddonebythesimplebalanceofaccuracyof0.001g as shown in Figure 2.The preparation of 12 different compositions are done for the non–hybrid and hybridcomposites.

Compositions	**Weigh Percentage**
Copper	3.8-4.9
Chromium	0.10
Ferrous	0.5
Magnesium	1.2-1.8
Manganese	0.3-0.9
Silicon	0.5
Titanium	0.15
Zinc	0.25
Aluminium	90.7-92.6
Others	Reminder

Table 1: Compositions ofAl2024.

Material	**Density**	**Size of particles**
Al2024	2.78	80 µm
B4C	2.52	100nm
Graphite	2.266	90 µm

Table 2: Particles size and density of materials.

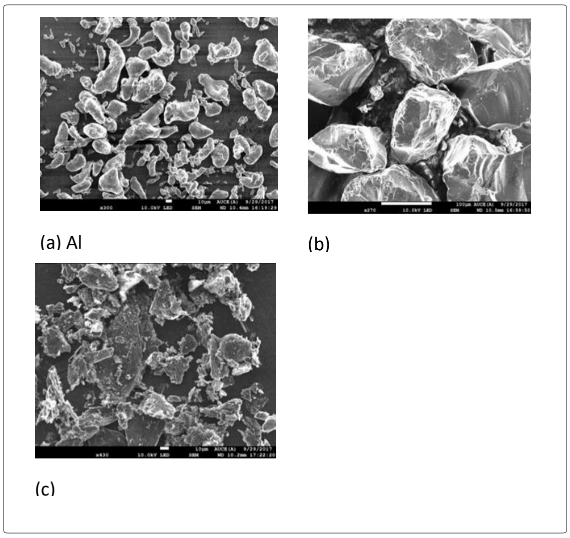

Fig 1: SEM images Materials

Pre-mixing of powders: The distribution of particles plays a vital role in the composite properties. For making the properties homogeneous though out it sections can be done by the proper mixing of reinforcements and base metal only. This can be done by usinghigh speed ballmillingmachineofspeed400rpmforthetimeof30minutes The powders to balls ratio is followed by 10:1.These process was carried

out at inert gas (organ) conditions (Figure 3).

IV SEM ANALYSIS

Scanning electron microscope (SEM) is one the type of electron micro scope which scans the sample with focused beam of elections. SEM can gives the information about sample contains with less than 1 (one) nano meter accuracy. The following gives the SEM images for

Al2024,Al2024,Gr,Al2024,Gr,B4CandAl2024,B4C.Allth espectrumreports were taken from jyothispectro analysis laboratories and report shown in digital form (Figures 4 and5)

Figure 2: Simple balance.

Figure 3: High speed ball milling machine.

Figure 4: SEM equipment.

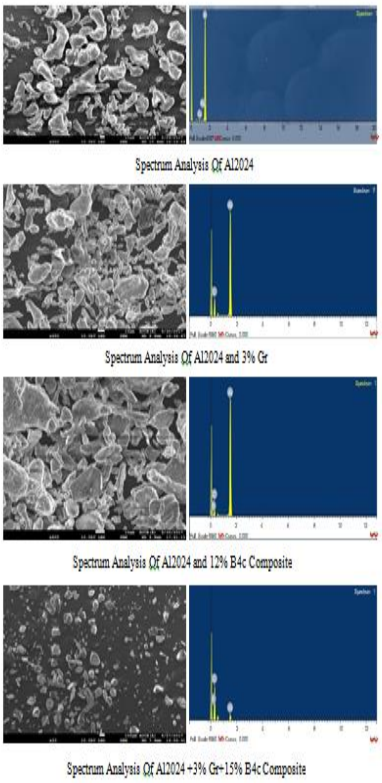

Figure 5: FESEM powder mixtures.

Fabrication of pellets: By using compression testing machine pellets are manufactured by the applied pressure of 400 mpa. In ctm load appliedisslowlyprogressiveloadandattheloadismaintainedfor time of 45 s. Separate die are manufactured with diameter of 15 mm andlengthof60mm.Thesizeobtainedpilletsare15mmdiameter and lenth of 35 mm. By filling the die with blended powders and placed in the ctm for applying load. The load applied is very slow manner and after reaching the required level there will be maintaining of load at thathighpressurefortimeof45s(Figures6-9).

Sintering: Sintering process makes the pellets into specimens for the testing purpose. This can be done by using muffle furnace of capacity 1500°C. All the pellets are placed in muffle furnace for sintering purpose at temperature of 600°C for the time of 3 hours (Figures 10 and11).

Hardness testing: The **Vickers hardness test method**, Since the test indentation is very small in a Vickers test, it is useful for a variety of applications: testing very thin materials like foils or measuring the surface of a part, small parts or small areas, measuring individual microstructures,ormeasuringthedepthofcasehardeningbysectioning a part and making a series of indentations to describe a profile of the change in hardness. By the successfully poling of specimens theseare further examined hardness values by using Vickers hardness tester of indenter dia of 0.25 inch. All the readings are plotted in the Table 3, Figures 12 and 13.

Heat treatment: By the successful manufacturing and sintering of specimens and conducting both density and harness testing of components subjected to heat treatment process. The heat treatment procedure isdonebytheheatinginmufflefurnace.Thetotalprocedureconsists two stages of operation in the first stage the specimens are subjected to around 490°C for 3 hours that is followed by quenching in the water. In the second stage process of specimens is subjected to natural aging process for the time of 18 hour to be became uniform grain growth of materials uniform by furnace cooling (Figures14-16).

Figure 6. Compression Testing

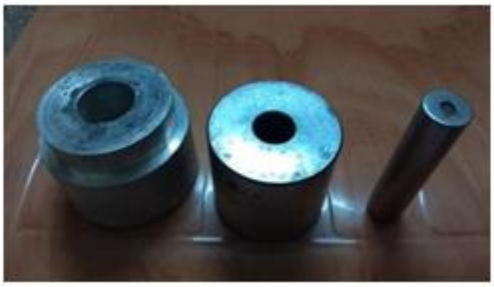

Figure 7: Die for manufacturing of pellets.

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Figure 8: Working position of compression testing machine.

Figure 9: Pellet eject from die.

Figure 10: Mufflefurnace.

Figure 11: Pellets in furnace.

Figure 12: Micro Vickers hardness tester

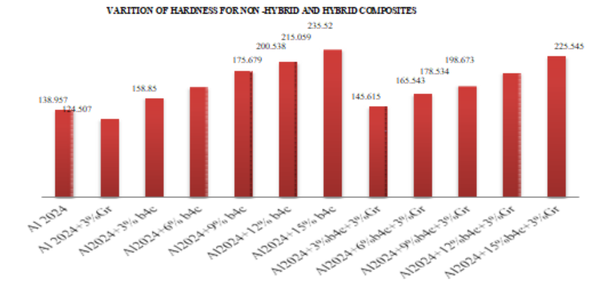

Figure 13: Graphical represetion of hardness values.

S. No	Composition	Trial 1			Trail 2			MICRO VHN
		D1	D2	VHN	D1	D2	VHN	
1	Al_{2024}	82.31	82.40	135.20	81.75	135.20	142.70	138.957
2	Al_{2024}+3%Gr	94.32	94.25	111.09	82.68	111.09	137.50	124.507
3	Al_{2024}+3% B_4C	80.15	80.06	157.750	80.71	80.01	159.950	158.850
4	Al_{2024}+6% B_4C	75.96	76.20	174.069	79.71	161.60	176.089	175.679
5	Al_{2024}+9% B_4C	73.84	78.06	199.438	79.09	153.00	201.638	200.538
6	Al_{2024}+12% B_4C	65.37	73.77	214.049	73.34	84.19	216.069	215.059
7	Al_{2024}+15% B_4C	76.80	76.03	234.420	85.80	154.70	236.620	235.520
8	Al_{2024}+3% B_4C +3%Gr	79.71	79.21	144.515	62.84	123.70	146.715	145.615
9	Al_{2024}+6% B_4C +3%Gr	80.92	60.71	164.443	80.08	78.06	166.643	165.543
10	Al_{2024}+9% B_4C +3%Gr	70.54	70.50	177.634	80.15	170.06	179.434	178.534
11	Al_{2024}+12% B_4C +3%Gr	91.18	91.12	197.773	81.37	68.62	199.573	198.673
12	Al_{2024}+15% B_4C +3%Gr	78.12	79.00	224.645	69.09	68.70	226.445	225.545

Table 3: Hardness values for specimens.

Figure 14: Arrangement of muffle furnace with argon gas.

Figure 15: Arrangement of specimens in muffle fumace before heat treatment

Hardness measurement of heat treated composites: Hardness measured by the micro Vickers hardness testing equipment with indentor diameter of .25 inch for that load applied of 5 kg for time of 30 s of model ASTM E-384 (Figures 17-19, Tables 4 and 5).

Figure 16: Arrangement for cooling purpose.

Figure 17: Vickers hardness reading position.

VI DENSITY MEASUREMENT:

By using the Archimedes principle the density of all of available components are measured by the arrangements with add use of simple weighing machine and distilled water for effective measurement. The Density of the respective specimens was determined basically by measuring the mass and the volume by using the balance and the measuring cylinder respectively. It is then estimated from the formula givenbelow.

TheDensityiscalculatedbyusingArchimedesprincipleby using sensitive balance and specimen weight in air is taken andweightofspecimenfloutonwaterthenbycalculatingtheweightsdensitywill obtain (Figures 20, 21 and Table6).

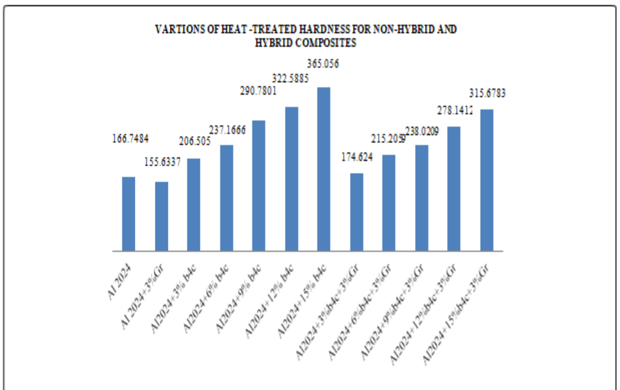

Figure 18: Graphical representation of heat-treated hardness value.

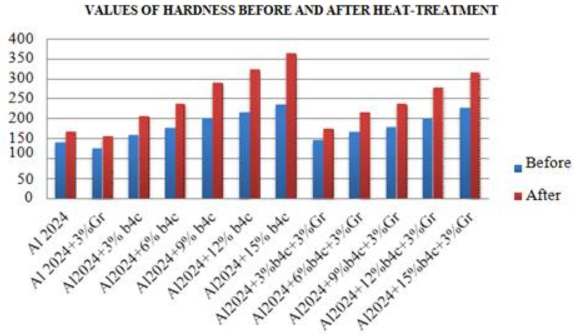

Figure 19: Graphical representation of before and after heat-treated hardness values.

1	Al_{2024}	76.15	74.16	165.7484	73.17	74.71	167.7484	166.7484
2	Al_{2024}+3%Gr	79.15	78.14	154.6337	72.17	73.71	156.6337	155.6337
3	Al_{2024}+3% B_4C	74.96	72.36	205.5050	72.27	72.71	207.5050	206.5050
4	Al_{2024}+6% B_4C	72.84	71.81	236.1666	69.72	73.71	239.1666	237.1666
5	Al_{2024}+9% B_4C	64.37	63.67	289.7801	64.72	74.71	291.7801	290.7801
6	Al_{2024}+12% B_4C	75.80	74.80	321.5885	63.71	75.71	323.5885	322.5885
7	Al_{2024}+15% B_4C	78.71	77.71	364.056	61.71	80.71	366.056	365.056
8	Al_{2024}+3% B_4C +3%Gr	78.71	76.71	173.6240	59.61	79.71	175.6240	174.6240
9	Al_{2024}+6% B_4C +3%Gr	79.92	78.92	216.2059	58.71	78.71	216.2059	215.2059
10	Al_{2024}+9% B_4C +3%Gr	69.54	68.52	237.0209	56.71	79.71	236.0209	238.0209
11	Al_{2024}+12% B_4C +3%Gr	90.18	89.18	276.1412	55.71	76.71	278.1412	278.1412
12	Al_{2024}+15% B_4C +3%Gr	77.12	76.12	314.6783	56.71	74.71	316.6783	315.6783

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Table 4: Heat-treated hardness values for specimens

S.no	Composition	Before	After
1	Al2024	138.957	166.7484
2	Al2024+3%Gr	124.507	155.6337
3	Al2024+3% B4C	158.850	206.5050
4	Al2024+6% B4C	175.679	237.1666
5	Al2024+9% B4C	200.538	290.7801
6	Al2024+12% B4C	215.059	322.5885
7	Al2024+15% B4C	235.520	365.056
8	Al2024+3% B4C +3%Gr	145.615	174.6240
9	Al2024+6% B4C +3%Gr	165.543	215.2059
10	Al2024+9% B4C +3%Gr	178.534	238.0209
11	Al2024+12% B4C +3%Gr	198.673	278.1412
12	Al2024+15% B4C +3%Gr	225.545	315.6783

Figure 20: Sample placed in water.

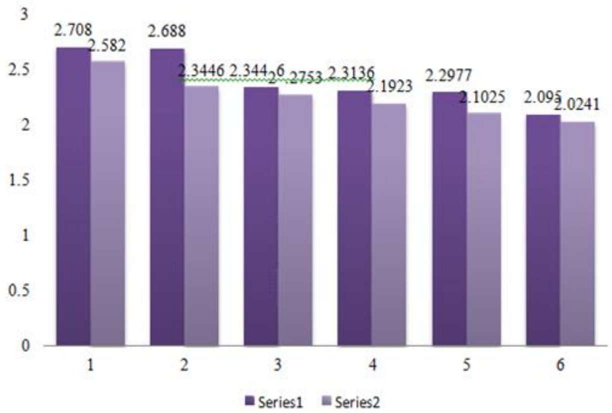

Figure 21: Density varitions of nonhybrid (1) and hybrid (2) composites.

Table 5: Change in hardness before and after heat treatment

Composition	Mass in Air (grams)	Mass in Water (grams)	Density (g/cm³)	Average Density (g/cm³)
Al_{2024}	11.448	4.052	2.825	2.708
	11.649	4.461	2.611	
	11.243	4.182	2.688	
Al_{2024}-3%Gr	10.497	4.2	2.499	2.582
	9.925	3.85	2.577	
	4.309	1.613	2.671	
Al_{2024}-3%B_4C	11.948	4.231	2.823	2.688
	10.881	3.982	2.732	
	9.712	3.872	2.509	
Al_{2024}-6% B_4C	9.463	4.027	2.349	2.3446
	9.032	3.792	2.381	
	8.002	3.472	2.304	
Al_{2024}-49%B_4C	10.089	4.027	2.311	2.3136
	9.062	4.125	2.196	
	8.463	3.476	2.476	
Al_{2024}-12% B_4C	12.071	5.131	2.352	2.3977
	9.172	4.382	2.093	
	8.033	4.203	1.911	
Al_{2024}-15% B_4C	10.013	4.721	2.120	2.095
	9.092	4.086	2.225	
	8.135	4.192	1.940	
Al_{2024}-3%Gr-3% B_4C	11.548	4.571	2.526	2.5473
	10.527	4.425	2.378	
	9.531	3.488	2.738	
Al_{2024}-3%Gr-6% B_4C	9.563	4.092	2.336	2.2753
	9.066	3.825	2.215	
	8.012	3.523	2.274	

Al_{2024}-3%Gr-9% B_4C	10.151	4.523	2.244	2.1923
	9.082	4.182	2.171	
	8.592	3.971	2.163	
Al_{2024}-3%Gr-12% B_4C	12.571	5.231	2.403	2.1025
	9.271	4.595	2.017	
	8.131	4.306	1.888	
Al_{2024}-3%Gr-15% B_4C	10.235	4.921	2.077	2.024
	9.173	4.182	2.193	
	8.231	4.595	1.793	

VI RESULT AND DISCUSSION

Non-hybrid and hybrid composites are fabricated by using powdermetallurgytechnique.Thereinforcementsareobserved using microscope for various pixels. Weight of all compents are taken in both air and water and density calculated in by usingairchimedesprincple(Table3).Thedecreaseindensityis observed in both hybrid and non-hybrid composites compared to base metal matrix composite as the B4C percentage is increased.

While comparision of these two (hybrid and non-hybrid) hybrid composites were having high density than non-hybrid composites.

By the aid of micro vickers hardness testing equipment hardnessofthenanocompositeswererecorded(Table4).With theincreasinginthepercentageofB4Chardnesswasincreased andgiventhehighestvalueofhardnessat15%ofreinforcment of B4C in both the hybrid and non-hybrid composites. And the compression in hardness value (micro hardness number) of non–hybrid composites(Al+B4C) are having highest hardness value than that of hybridcomposites(Al+B4C+Gr).

Bythecompressionofheattreatedhardnessforthebothhybrid and non-hybrid composites non hybrid composites shows higher hardness than hybrid composites. Out of all theavilable composites non hybrid composites with 15% of B4C having the hardness of highest value and had very much difference with hybrid composites of 15% of B4C and 3% Graphite. The difference in the hardness was due to the addtion of Graphite that having machinabilityproperty.

VII CONCLUSIONS

- Thesuccessfulfabricationofcompositesweremanufac turedby using powder metallurgytechnique.
- Superior distributions of reinforcement are done by the aid ofhigh- speedballmilling (RETRSCHPM100)at400rpm.
- Microstructure of all composites is shown that uniform distribution ofreinforcement.
- SEM analysis shows the result that composite contains of matrix and reinforcement in the givencomponent.
- Hardness of all the composites increased tremendously by the heattreatment.
- All composites that is hybrid and non-hybrid composites are more harder than the base material expect 3% of Gr only this is due to addition of graphite which having machinability capability.
- Hybrid composites were less harder when compared with non- hybrid composites and out of all composites the composition of Al2024+15%ofB4Ch adhighesthardnessnumber.
- Density of hybrid and non-hybrid composites was less than that of basematerial.

As the percentage of reinforcement increase the density of component decreases which gives optimum strength to weight ratio. Densityofallspecimensaredecreasedwithanincreasing of B4C in Non hybridcomposites

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