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The Performance Analysis of Aluminum Based Red Mud Metal in Heat Treatment

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ABSTRACT
The need for composite materials has become a necessity for modern technology, due to the improved physical and mechanical properties. Metal matrix composites (MMC) have been developed in recent years. MMC_s are very important because of their high ratio of strength and weight, high young modulus and high abrasive properties. Metal Matrix Composites have emerged as a class of material capable of advance structural, aerospace, automotive, electronic, thermal management and wear applications.
In this paper attempt will be made to fabricate aluminum based Metal Matrix Composites (MMC) using Red Mud is a reinforcement material with the help of powder metallurgy method. Since Red mud contains lot of alumina oxide it could be used as a reinforcement material for enhancing the mechanical properties of aluminum materials. In this work the MMC will be fabricated for different proportion of red mud (3, 4 & 7 %) with different load, sintering time and sintering temperature. Then the effect of the above parameters will be analyzed to identify the suitable condition for fabrication of MMC based on the outcome of the mechanical properties. In this work the average particle size of aluminum and red mud were used in the range of 150 to 300 and 1.807 to 4 µm.Sintering temperature and time were maintained in the range of500-600^{0}C for 45-75 min. The fabricated materials will be subjected to various mechanical testing like compressive strength, hardness and various mechanical properties like young modulus and shear modulus without heat treatment. The same kind of specimen will be subjected to T 6 heat treatment process; the effect of heat treatment on the fabricated specimen will be analyzed and compared with without heat treatment specimen.

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I. LITERATURE REVIEW

In recent scenario, there is an increasing trend towards using composite materials in order to achieve better performance in engineering materials. Thus production and application of metal matrix composites (MMC) have increased in recent years (Kok M.) MMC_s are very important because of their high strength to weight ratio, high Young modulus and wear resistance properties, when compared to most conventional materials properties. Therefore, MMC are being used for wide variety of application such as, connecting rod, automobile drive shafts, cylinder liner, cylinder block, rotors (RasitKoker et al 2005) heat sink crane hearing and motor blocks.

To fabricate MMC, metallic matrix materials should be embedded with reinforced materials, which is in the form of continuous fibers, short fibers, chopped fibers, whiskers or particulates (Yusuf Sahin, 2010). In general, aluminum, copper, nickel, silver, zinc, magnesium will be used as matrix material and Silicon carbide (Yusuf Sahin, 2010), Alumina oxide (Sun Zhiqiang et al 2005, Arslan G et al 2001, Turn S et a; 2001) silicon nitride (Sun Zhiqiang et al 2005,Fujii Hidetoshi et al 1993, Jenfin Lin et al 2001) will be used as reinforcement material. Among the different matrix material aluminum and its alloys are promising materials in automobile and aerospace application owing to their excellent mechanical properties (F. Akhlaghi et al 2009) and other major advantage is better corrosion resistance properties, moreover aluminum cheaper than other light matrix materials. However, low wear resistance of pure aluminum is a serious drawback in using many applications. Addition of ceramic reinforcement materials in the aluminum matrix material would improve the strength, hardness, wear resistance and corrosion resistance of the matrix materials. (Mehdi Rehimian et al 2011, Toress B et al 2002, Sahin Y 1996). In order to embedded thereenforcement material with matrix material, there are different manufacturing methods are available).

The manufacturing methods are classified as: liquid state processing, solid state processing and deposition techniques. The liquid state processing includes, stir casting, semi solidprocessing (BekirSadikUnlu 2008), spray casting, infiltration and in situ processing. Solid state processing includes powder metallurgy (BekirSadikUnlu 2008, Liu B et al 1994), diffusion bonding, pultrusion, and attriter milling. Deposition technique includes chemical vapour deposition, and physical vapour deposition.

However liquid state processing methods has two major drawbacks, firstly the ceramic particles are not wetted with matrix material and secondly, the particles tend to sink or float depending on their density relative to the liquid metal and so that dispersion of the particles are not uniform, where as solid state process, especially powder metallurgy process offers uniform distribution of reinforcement with matrix material. (BekirSadikUnlu 2008, Bai M et al 1995, Nesarikar AR et al 1991, Soliman FA et al 1997) While using a powder metallurgy technique for fabrication of MMC, best mechanical properties can be attained since reinforcement materials are homogenously distributed over the matrix material (HosseinAbdizadeh et al 2011).

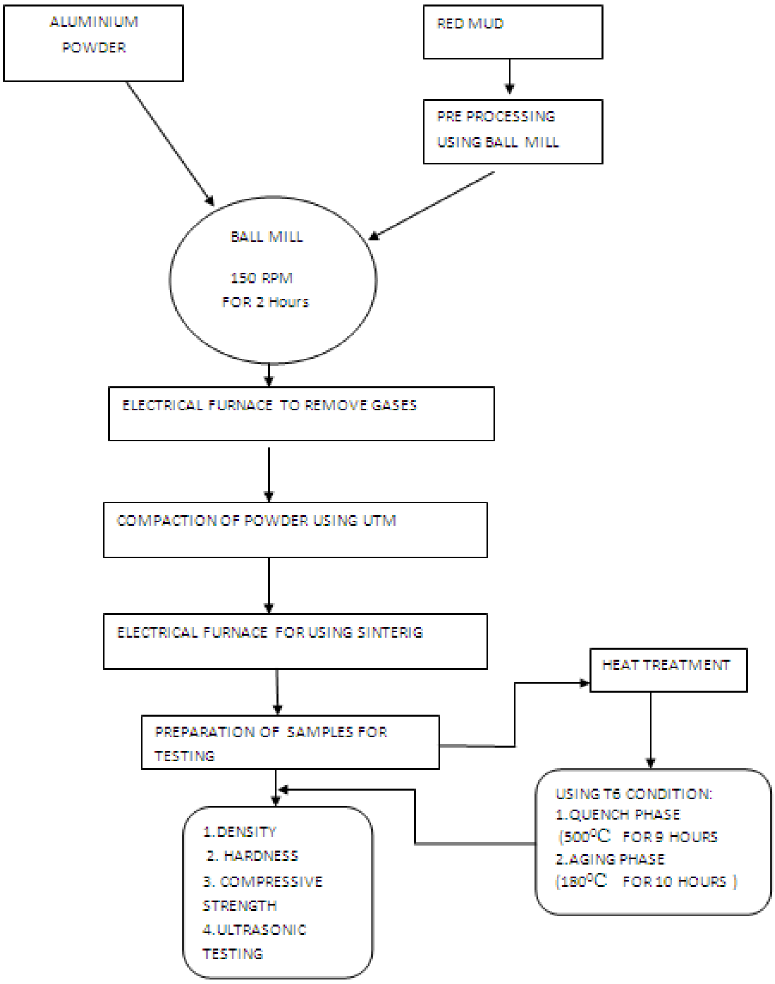
In addition to that, in this process low temperature is used for fabrication when compared to melting process thus it avoids chemical reaction between the matrix and reinforcement material (Mehdi Rehimian et al 2011, Toralba et al 2003). Another advantage of powder metallurgy technique is in its ability to manufacture near net shape products at low cost and give good dimensional tolerance for the complex geometries (M. Reihanian et al 2011, ASM Handbook vol7 1998).

II. OBJECTIVES AND METHODOLOGY

Proposed Methodology:

The proposed methodology for the present study is shown in the fig. 1. The matrix can be selected on the basis of oxidation and corrosion resistance or other properties. Generally Al, Ti, Mg, Ni, Cu, Pb, Fe, Ag, Zn, Sn and Si are used as the matrix material, but Al and Mg are used widely. Now a day's researchers all over the world are focusing mainly on aluminum because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. In addition, literature also reveals that most of the published work has considered aluminum-based composites with their attractions of low density, wide alloy range, heat treatment capability and flexibility. So Aluminum powder (AP 30 – grade) is selected as a base material for our project. The average particle size of aluminum was 300µm. Reinforcement increases the strength stiffness and the temperature resistance capacity and lowers the density of MMC. In order to achieve these properties the selection depends on the type of reinforcement, its method of production and chemical compatibility with the matrix. This huge amount of industrial by-products/wastes which is becoming a client for increasing environmental pollution & generation of a huge amount of unutilized resources/ Red mud is used as reinforcement material for this study and powder metallurgy technique is employed to fabricate the sample specimen.

Figure 1. Methodology



III. MATERIALS AND METHODS

1 Metal Matrix Composites

At First phase, considering various composite material literatures, metal matrix composite is selected as main theme of this project and the properties of metal matrix composites are studied. Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials.

1.1 Matrix material

The matrix can be selected on the basis of oxidation and corrosion resistance or other properties. Generally Al, Ti, Mg, Ni, Cu, Pb, Fe, Ag, Zn, Snand Si are used as the matrix material, but Al an Mg are used widely. Now a day's researchers all over the world are focusing mainly on aluminum because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. In addition, literature also reveals that most of the published work has considered aluminum-based composites with their attractions of low density, wide alloy range, heat treatment capability and flexibility. So Aluminum is selected as a base material for our project.

1.2 Reinforcement Material

Reinforcement increases the strength stiffness and the temperature resistance capacity and lowers the density of MMC. In order to achieve these properties the selection depends on the type of reinforcement, its method of production and chemical compatibility with the matrix. MMC reinforcements can be metallic (such as tungsten and cobalt), non-metallic (most often carbon, graphite, or boron), or ceramic (for example, silicon carbide (SiC), aluminum oxide (Al_2O_3), boron nitride, red mud, titanium diboride, titanium carbide, or boron carbide). Here selected reinforcement materials is red mud which posses high strength rigidity, corrosion resistance, wear resistance, surface finished etc,

Cold uniaxial pressing:

Elemental metal, or an atomized are alloyed, powder is mixed with a lubricant, and pressed at pressures of say, maximum of 300kN in metal dies. Cold compaction ensures that the as-compacted, or 'green', component is dimensionally very accurate, as it is moulded precisely to the size and shape of the die, shown in fig. 2.

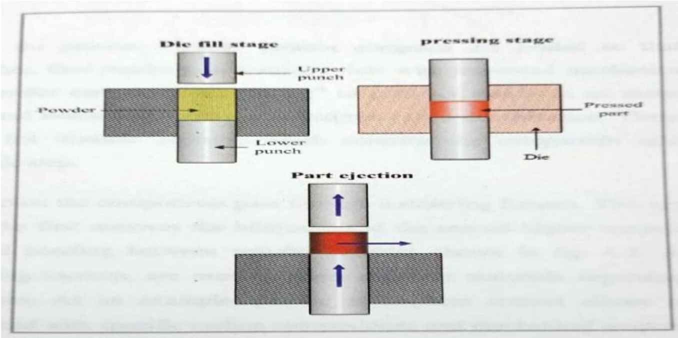


Figure 2. Cold uniaxial pressing process

Irregularly shaped particles are required to ensure that the as-pressed component has a high green strength from the interlocking and plastic deformation of individual particles with their neighbors.

Experimental study

1. Experimental Procedure

The following steps are followed to fabricate the aluminum based red mud material using power metallurgy method.

Initially the specimens that are to be analyzed are to be performed from pure aluminum and red mud powder. The following steps were undertaken to prepare the specimen.

1. Powder mixing
2. Die preparation
3. Loading the powder into the die
4. Compacting
5. Sintering

1.1 Powder Mixing

Required amount of aluminum and red mud were measured and taken as per the required composition and aspect ratio based on volume and mass calculation. Ball mill is used for the powder mixing process to get the uniform distribution in the MMC.

Ball Mill Description

A ball mill, a type of grinder, is a cylindrical device used in grinding (or mixing) materials like ores, chemicals, ceramic raw materials and paints. Ball mills rotate around a horizontal axis, partially filled with the material to be ground plus the grinding medium. Different materials are used as media, including ceramic balls, pebbles and stainless steel balls. An internal cascading effect reduces the material to a fine powder. Industrial ball mills can operate continuously, fed art one end and discharge at the other end. Large to medium-sized ball mills are mechanically rotated on their axis, but small ones normally consist of a cylindrical capped container that sits on two drive shafts (pulleys and belts are used to transmit rotary motion). A rock tumbler functions on the same principle. Ball mills are also used in pyrotechnics and the manufacture of black powder, but cannot be used in the preparation of some pyrotechnic mixtures such as flash powder because of their sensitivity to impact. High- quality ball mills are potentially expensive and can grind mixture particles to as small as 5 µm, enormously increasing surface area and reaction rates. The grinding works on principle of critical speed. The critical speed can be understood as that speed after which the steel balls (which are responsible for the grinding of particles) start rotating along the direction of the cylindrical device; thus causing no further grinding.

Ball mills are used extensively in the mechanical alloying process in which they are not only used for grinding but for cold welding as well, with the purpose of producing alloys from powders. One of most commonly used mills is the SPEX Mill.

Grinding

Since Red mud is very hard material and inflammable, reagent Ethanol was used. The balls and powder were completely immersed in Ethanol. Ball to powder ratio 20:1 was kept for fast milling.

Grinding of red mud:

Table 1 Size of Red Mud

NANO SIZE	0.180 MICRONS
TIME (HOURS)	36

The chart gives red mud size which is tested using particle zeltaanalyser.
Particle size chart ;

Results:Table 2.

Z average d.nm 182.1		Dia in mm	%intensity	Width (nm)
Pdl :0.331	Peak 1	184.3	100.0	04.29
Intercept 0.912	Peak 2	0.000	0.0	0.000
Result quality	Peak 3	0.000	0.0	0.000

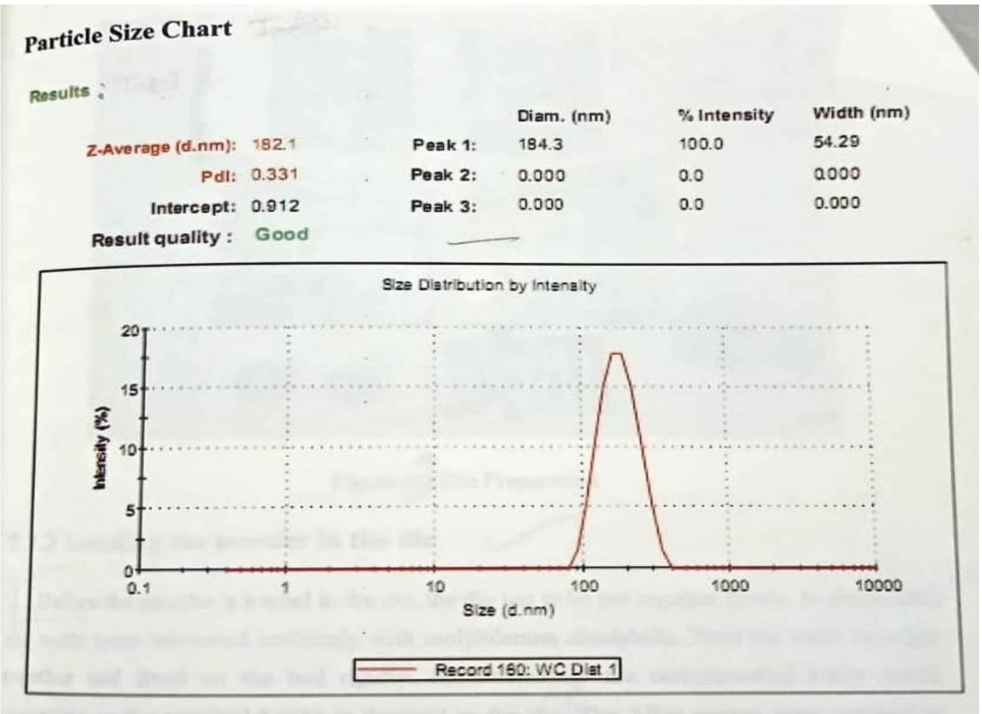


Figure 3. Particle size distribution

1.2 Die preparation

The composite powder has to be compacted into cylindrical perform of diameter 20mm and varying hights. The specimens were prepared for two different aspect ratios. Asplit was performed from mild steel in order to meet the above requirements. It basically consists of the die walls containing the cavity for the cylindrical perform.

Figure 4. Die preparation

1.3.Loading the powder in the die

Before the powder is loaded in the die , the die has to be put together firmly. In the process die walls were lubricated uniformly with Molybdenum disulphide. Then the walls were put together and fixed on the bed rigidly. Simultaneously the corresponding lower punch according to the required height is dropped in the die.

Mixing of Aluminum with red mud:

In Metal matrix composite, the method of the introduction of particles into the matrix melt is one of the most important aspects in composition . Here mixing is done by using ball mill as explained previously for several minutes.

Table 3. Components of Aluminum with Red Mud

COMPOSITION	5% RM WITH AL	10% RM WITH AL	15% RM WITH AL
TIME (MINUTES)	120	120	120

The compacting was carried in 100 ton UTM . Once the setup is ready and placed in between the two jaws of the UTM. It was switched on and the lower jaw was moved upwords till the self weight. Then the displacement and the load were reset to zero. During the compacting the interspacing between the powders is reduced at every step. The loading is carried out till the formulated load is obtained.

The compacted specimens were then placed in a muffle furnace for sintering. Sintering is usually carried out below the melting point of the lowest melting metal which in this case is aluminum (melting point = 660ºC). Sintering is essentially a process of bonding soiled bodies by atomic forces.

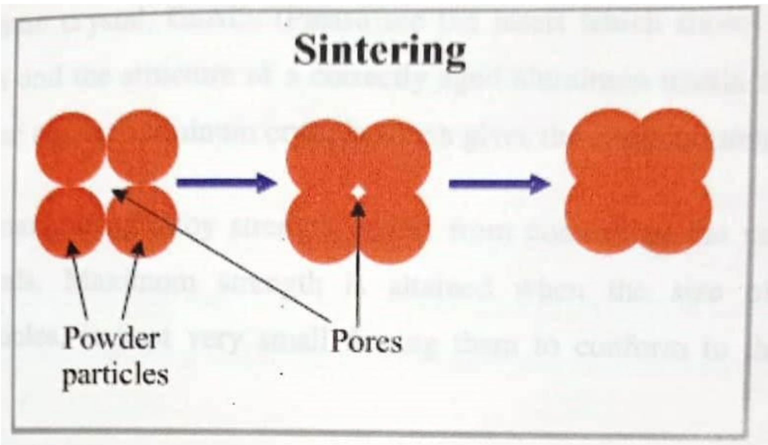


Figure 5. Sintering Process

T-6 Heat Treatment Process: T-6 = 30%Increase in strength

The First of T6 heat treatment is called the Quench Phase.In this phase the alloy is heated to 920 ºF for 9 hours causing the copper in the ally to become dissolved in the aluminum and forming what is called a "Single Phase Alloy" . If allowed to air cool naturally, the copper will tend to reconstitute , or reform itself within the alloy. However , when the heatedalloy is cooled rapidly by water quenching the reformation of the copper is retarded and the aluminum, supersaturated with copper , is locked into the "Single Phase Alloy" state .

Expressions to calculate mechanical behavior using ultrasonic testing equipment

$\rho = W_{a} / (W_{a}-W_{b}) (\rho_{b})$ Where $W_a$is the weight in air ,$W_b$is the weight in water and ρ_b is the density of water . The ultrasonic velocity U and U_S of the material$_{IS}$ obtained using the relation U= 2d/t where d is the thickness of the sample and t is the precise transit time .

Longitudinal modulus L = U2l

Shear modulus G =U_s2l

Bulk modulus K = L- (4/3)G

Poisson ratio S = (L-2G)/2(L-G)

Young Modulus E = (1+S) 2G

Attenuation Co-efficient α_a= 1/2dln (1t/1r)

Acoustical Impedance Z = $U_L \rho$

Thermal expansion co-efficient α_p= 23.2(U_L-0.57457)

Internal friction = $Q^{-1} = \alpha_a/(8.66 \pi f U_L)$

Packing Density V_T = 1 /.072 (0.5 - σ)

Micro hardness H = (1-2σ) E/6 (1+σ)

Fracture toughnessF = 0.016 $(Y/H)^{.5}$ $(F/C^{1.5})$

Fracture surface energy = SE =mF^2 (1-2σ)2Y

RESULTS AND DISCUSSIONS

Based on the experimental results , the calculated and observed values are tabulated.

The effect of process parameters on density without heat treated at different sintering temperature at 60 min at 300Kn load.

Table 4 and Figure 6 Sow the effect of process parameters on density for various fabrication conditions. The fig 6 shows that increase in sintering time and temperature will increase the density.

Table 4 : The effect of process parameters on density without heat treated at different sintering temperature , at 60 min at 300 Kn load.

Weight % of reinforcement	Applied load in kN	Sintering temp in ºC			Sintering time in min	Density at500 ºC	Density at550 ºC	Density at 600 ºC
Pure Al	300	500	550	600	60	2.391	2.426	2.487
5% of RM	300	500	550	600	60	2.411	2.486	2.651
10 % of RM	300	500	550	600	60	2.489	2.511	2.684
15 % of RM	300	500	550	600	60	2.526	2.614	2.739
20 % of RM	300	500	550	600	60	2.612	2.677	2.741

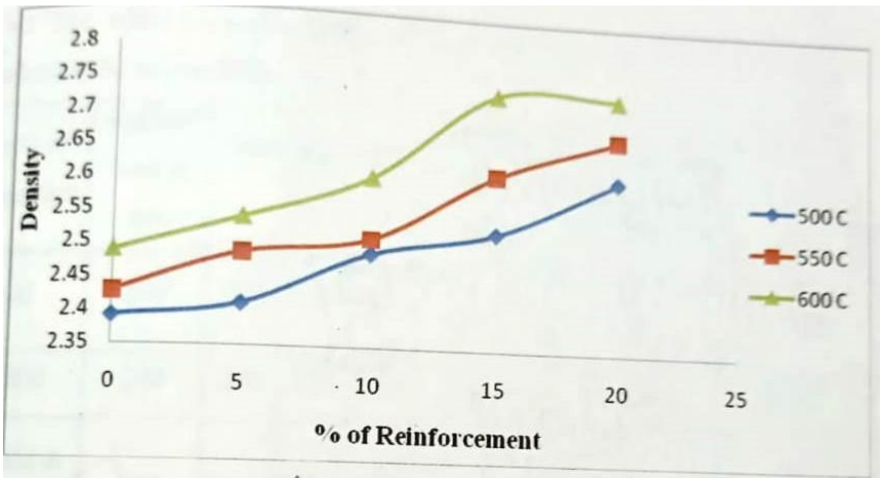


FIGURE 6 ;% of Reinforcement Vs Density

The figure 6 shows that increase in sintering time and temperature will increase the hardness, Upto 5% of reinforcement there is an increase in hardness afterwards there is a decrease in hardness

Table 5 : The effect of compressive strength without heat treated at different sintering temperature , at 60 min at 300 Kn load

Weight % of reinforcement	Applied load in kN	Sintering temp in ºC			Sintering time in min	Compre - ssive strength 500 ºC	Compre- ssivestrength 550 ºC	Compre - ssivestrength 600 ºC
Pure Al	300	500	550	600	60	155.41	158.94	165.23
5% of RM	300	500	550	600	60	153.67	157.53	161.49
10 % of RM & 90% of Al	300	500	550	600	60	110.23	111.36	114.45
15 % of RM & 85% of Al	300	500	550	600	60	78.54	79. 96	82.97
20 % of RM	300	500	550	600	60	76.47	79.19	75.35

From the table 5, the effect of process parameters on hardness for various fabrication conditions..

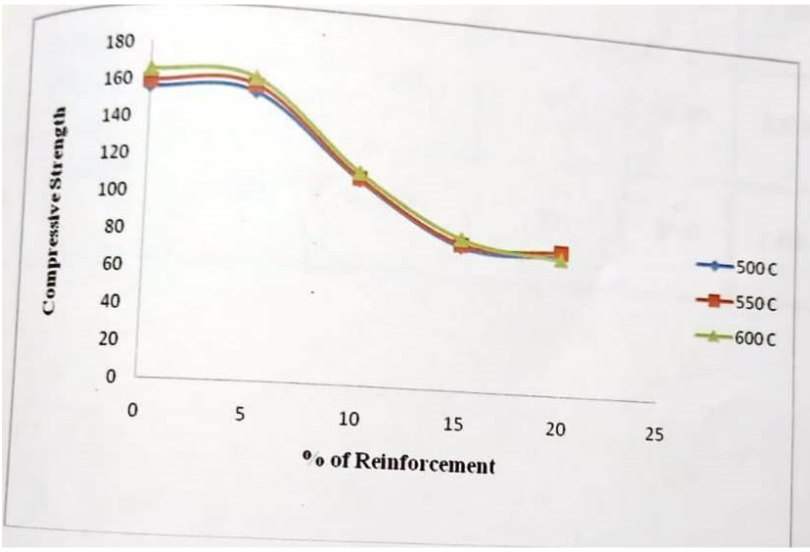


Table 6; The effect of process parameters on hardness and density without heat treated at 600 ºC ,60 min and at 300kN load

Weight % of reinforcement	Applied load in kN	Sintering temp in ºC	Sintering time in min	Hardness value in (BHN)	Density in (gm/cm^3)
Pure Al	300	600	60	41.77	2.4877
3% of RM &97% of Al	300	600	60	60.7917	2.499
5 % of RM & 95% of Al	300	600	60	64.599	2.539
7 % of RM	300	600	60	58.36	2.626

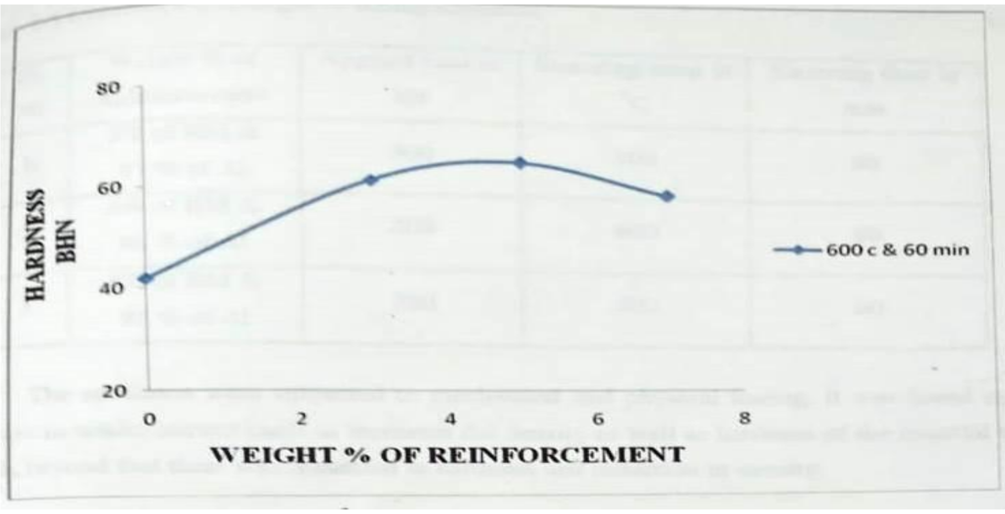


Figure 7 ; %of Reinforcement Vs Hardness

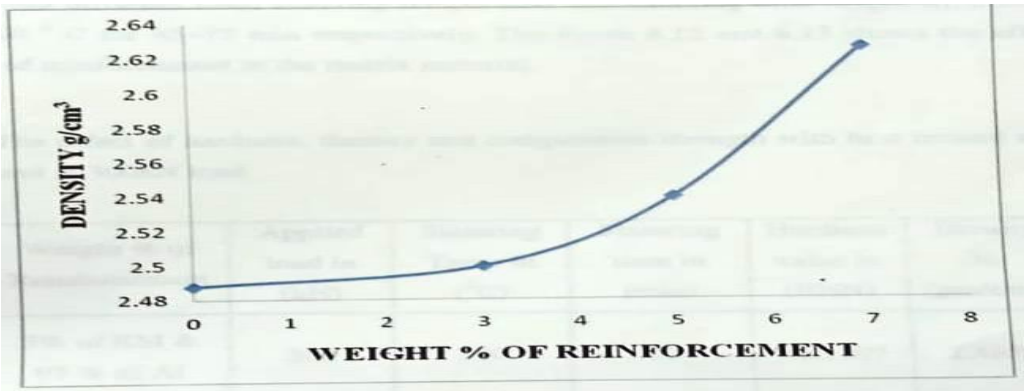


Figure 8 ; %of Reinforcement Vs Density

Table 7; Different Percentages of Reinforcements

Weight % of reinforcement	Applied load in kN	Sintering temp in ºC	Sintering time in min
3% of RM &97% of Al	300	600	60
4 % of RM & 96% of Al	300	600	60
5 % of RM & 95% of Al	300	600	60

Table : 8 . The effect of hardness, density and compressive strength with heat treated at 600 ºC ,60 min and at 300kN load

Weight % of reinforcement	Applied load in kN	Sintering temp in ºC	Sintering time in min	Hardness value in (BHN)	Density in (gm/cm^3)
3% of RM &97% of Al	300	600	60	60.7007	2.4559
4 % of RM & 96% of Al	300	600	60	62.4084	2.4326

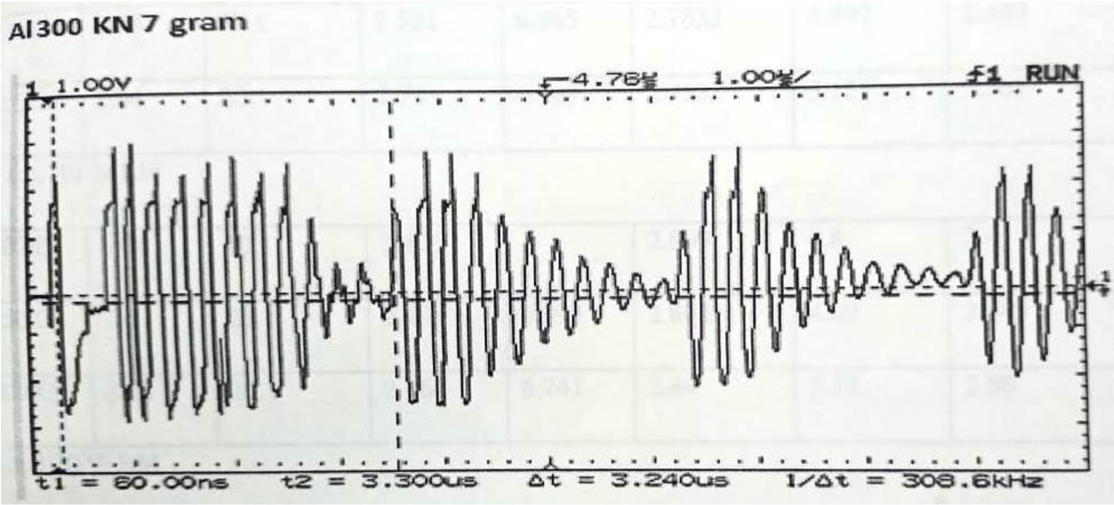


Figure 9 : Ultrasonic graph for load 300kN for 20 % Reinforcement

At 300 Kn ,7gm

Table 9: Observation and measurement of the fabricated specimen

9.1 Pure Aluminum

Pellet	Height	Diameter	Wt in Water	Wt in Air	Density	U_1	U_s
200 kN	8.1	20.1	2.632	6.795	2.5817	4.865	2.433
250 kN	8	20.1	2.644	6.9584	2.612	4.938	2.469
300 kN	8.02	20.1	2.622	6.8653	2.6183	5.013	2.507

9.2 5& RM

Pellet	Height	Diameter	Wt in Water	Wt in Air	Density	U_1	U_s
200 kN	8.11	20.1	2.556	6.978	2.7298	4.87	2.435
250 kN	8.08	20.1	2.521	6.885	2.7533	4.897	2.449
300 kN	8.04	20.1	2.531	6.969	2.7533	5.121	2.561

9.310& RM

Pellet	Height	Diameter	Wt in Water	Wt in Air	Density	U_1	U_s
200 kN	8.041	20.1	2.475		2.809	4.8	2.4
250 kN	7.6	20.1	2.408	6.893	2.862	4.89	2.445
300 kN	8.02	20.1	2.364	6.741	2.84	5.12	2.56

9.420& RM

Pellet	Height	Diameter	Wt in Water	Wt in Air	Density	U_1	U_s
200 kN	7.35	20.1	2.335	6.901	2.9553	4.482	2.241
250 kN	7.2	20.1	2.345	6.9673	2.9711	4.543	2.272
300 kN	7.1	20.1	2.33	6.9421	2.979	4.625	2.313

Table 10 . Calculated values of various mechanical properties

Pellet	Long.Mod	Shear Mod	Bulk Mod	Poisson Ratio	Young Modulus	Micro Modulus	Packing Density
200 kN	61.1043	15.282	40.779	0.33	40.749	1.699	2.316
250 kN	63.691	15.923	42.513	0.33	42.461	1.769	2.315
300 kN	65.798	16.456	43.912	0.33	43.88	1.829	2.316
200 kN	64.742	16.186	43.215	0.33	43.162	1.799	2.315
250 kN	64.025	16.513	44.063	0.33	44.013	1.836	2.316
300 kN	72.204	18.058	44.187	0.33	48.151	2.007	2.316
200 kN	64.719	16.179	43.201	0.33	43.144	1.798	2.315
250 kN	68.436	17.109	45.681	0.33	45.624	1.901	2.315
300 kN	74.449	18.162	49.695	0.33	49.632	1.901	2.315
200 kN	59.367	14.842	39.627	0.33	39.579	1.65	2.315
250 kN	61.32	15.337	40.922	0.33	40.896	1.705	2.316
300 kN	63.723	15.938	42.525	0.33	42.489	1.772	2.316

IV. CONCLUSION

Experiment has been carried out for different percentage of reinforcement, load, sintering temperature and sintering time. It has been absorbed that, the percentage of reinforcement more than 5% is not giving expected outcome on the output quality characteristics.

From the experiment result it was found beyond that 5% hardness, decrease while increases in reinforcement, sintering temperature and time.

Compressive strength of the specimen was reduced when compared pure aluminium while adding % of reinforcement compressive strength is decreases further at different sintering time.

The density of the composite rises while increases in percentage of reinforcement, sintering temperature and sintering time.

Use of T 6 heat treatment process considerably increases the mechanical and physical properties of the materials.

Ultrasonic test result revealed that the increase in % of reinforcement material gives the improved mechanical properties.

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