Effect of T6 type heat treatment on mechanical characterization of Al6061/Fe_2O_3 composites

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Abstract*— In recent era, Aluminium based alloy metal matrix composites (MMC) are acquisition wide spread recognition in various aerospace and automobile devices. In the present study, the results of Mechanical characterization for Al6061 reinforced with Fe_3O_3 up to 0-6 wt% were prepared with the help of stir casting method. The cast matrix alloy and its composites are subjected to a solution zing treatment at a temperature of 530 ± 20^0C for 1 hour, followed by ageing at a temperature of 170 ± 20^0C for 6 hours. The mechanical characterization of as cast and T6 heat treated composites are checked as per ASTM standards and compared. Addition of Fe_2O_3 particulates into the Al6061 matrix improved the hardness and strength but reduces its ductility of the composites. In Al6061composites the sufficient improvement in hardness & tensile strength are not detected as the Wt% of Fe_2O_3 increases. The results also reveals that the there is enhanced in the mechanical characterization of heat treatment specimens. The homogeneous allocation of Fe_2O_3 particles in matrix composites is released by micro structure studies.

Key words:* *Al6061, Fe_2O_3, T6 type heat treatment, Yield strength

I. INTRODUCTION

Metal–matrix composites (MMCs) are the most compromising materials in upgrading mechanical properties they are Hardness, Young's modulus, Yield strength and Ultimate tensile strength due to the presence of micro-sized reinforcement particles into the matrix. Aluminum-matrix composites (AMCs) reinforced with discontinuous reinforcements are widely used in Automotive, Military, Aerospace and Electricity industries because of their improved physical and mechanical properties[1-4]. Among all Al-alloys, 6061Al-alloy are broadly used in engineering applications like Transportation and Construction sectors as well where higher level mechanical properties involves tensile strength, hardness etc., are essentially required. A number of materials such as Sic, Al2O3, B4C, TiB2, ZrO2, SiO2, graphite and Fe2O3 (Hematite) are used as reinforcements to improve the properties of 6061Al alloy [5-9].

The mechanical properties of MMCs are very sensitive to the method of processing being used. Considerable improvements may be achieved by applying science-based modeling methods to optimize the processing procedure. Several methods are employed to prepare the composites containing powder metallurgy, melt techniques and squeeze casting. Notwithstanding, powder metallurgy gives off an impression of being the favored procedure in perspective on its capacity to give progressively uniform scatterings. Hot expulsion is commonly utilized as post-treatment to take the benefits of applying compressive powers and high temperatures, all the while [10-12].

In spite of the fact that powder metallurgy delivers better mechanical properties in MMCs, fluid state handling has some critical favorable circumstances. They are: better grid molecule holding, simpler control of lattice structure, effortlessness, ease of handling, closer net shape and the wide determination of materials. Fluid state manufacture of MMC's incorporates two techniques which rely upon the temperature at which the particles are brought into the dissolve. In soften blending process, the particles incorporate the temperature over the temperature of the fluids of the liquid amalgam, while in compo-throwing strategy the particles are fused at the semi-strong slurry temperature of the combination [13]. In the two procedures, the vortex is utilized for presenting fortification particles. Nonetheless, the liquefying procedure has two noteworthy issues right off the bat, the Ceramic particles are commonly not wetted by the fluid metal network, and besides, the particles will in general sink or buoy as per their thickness in respect to the fluid metal. Wettability can be characterized as the capacity of a fluid to spread on a strong surface and it speaks to the degree of close contact among fluid and strong. Therefore, it results in poor scattering of the fired particles, higher porosity and lower mechanical properties of the composite. This represents a great challenge of synthesizing cast MMC's. Poor wettability means that the molten matrix cannot wet the surface of the reinforcement the particles as a result simply float on the surface due to the large surface tension surface, high interfacial energy, and presence of oxide film on the surface of the melt. The improvement of wettability to a certain extent can be achieved by different methods such as mechanical agitation, preheating of the particles to remove the gases adsorbed by the particles

Surface, addition of alloying elements, use of surface coatings on reinforcing particles, etc. Another problem is the distribution of reinforcement particles in the molten matrix. Due to the density difference between matrix and reinforcement, these particles tend to float or settle in the molten matrix as a result agglomeration and clustering of the particles will occur. It has been reported that injection of particles with inert carrier gas is helpful in improving the distribution. Therefore, it is essential to develop a method for producing Al-MMC's taking account of incorporation and distribution reinforcing particles in the molten matrix [17].

The point of present examination is to synthesize 6061Al-Fe_2O_3 (Hematite) particulate MMC by stir casting method. In order to expand the wettability and appropriation of strengthening particles a novel three stage mixing combined with preheating of the reinforcing particles is being adopted and also to investigate the effects of different factors such as: (i) weight level of the particles (ii) Fabrication process on the microstructure and mechanical properties of the composites.

II. EXPERIMENTAL DETAILS

A. Aluminium alloy

Al 6061 is a pliable, tough, light weight, acquiescent metal with manifestation ranging from silvery to dull grey, depending on the surface roughness. 6061Al is not magnetic and not sparking. It is insoluble in alcohol; through it can be soluble in certain forms of water. The yield strength of pure Al is 7-11 MPa. Meanwhile 6061Al alloy have yield strength ranging from 200MPa to 600MPa. The chemical composition of matrix material is as shown in Table 1 determined using Atomic Absorption Spectrophotometer.

Al 6061 is precipitation solidifying aluminum composite, containing magnesium and silicon as its major alloying components. It has great mechanical properties and displays great weld capacity. For broadly useful use it is a standout amongst the most widely recognized composites of Alluminium. It is regularly accessible in pre-tempered evaluations, for example, 6061-O (solutionized) and tempered evaluations, for example, 6061-T6 (solutionized and misleadingly matured) and 6061-T651 (solutionized, stress-soothed extended and falsely matured). Table 2 demonstrates the physical and thermal properties of Al 6061.

B. Hematite (Fe_2O_3) as Reinforcement

The chemical formula of Hematite is Fe_2O_3. Likewise spelled as hematite, is the mineral type of iron oxide (Fe2O3), one of a few iron oxides. Hematite solidifies in the rhombohedra cross section framework, and it has a similar precious stone structure as limonite Hematite complete solid solution at temperatures above 950°C. Hematite (Fe_2O_3) is the most cost effective and widely used material in the family of engineering field.

C. Al based MMC preparations by stir casting route

Stir casting set up as shown in the Fig.1 comprised of obstruction heater and a stirrer gathering was utilized to blend the composite. The grid material utilized for the present examination is 6061Al-compound. The compound arrangement of network material is as appeared in Table 1 decided to utilize Atomic Absorption Spectrophotometer. Hematite (Fe_2O_3) particles with a size of 125 μm and with fluctuating measures of 2, 4 and 6 wt% are being utilized as fortifying material in the readiness of composites. Blend throwing strategy has been utilized for the planning of composites. At first, determined the measure of Al 6061 combination was raced into Go pot and superheated to a temperature of 7500C in an electrical opposition heater.

The heater temperature was controlled at a precision of ±500C utilizing a computerized temperature controller. An epic three phase blending joined with preheating of the strengthening particles is pursued. Hematite (Fe_2O_3) particulates were preheated to a temperature of 2500C in a stove to expel the adsorbed gases from the molecule surface and to keep away from high drop of temperature after expansion of particulates. Preheated Hematite (Fe_2O_3) particles were brought into the vortex of the liquid compound after powerful degassing utilizing strong hexachloroethane (C_2C_{l6}). Vortex is created with the assistance of a zirconium covered steel impeller.

The degree of joining of Hematite (Fe_2O_3) particles in the grid combination was accomplished in ventures of 3. For example the Aggregate sum of support required was determined and is being brought into the dissolve multiple times instead of presenting at the same time. At each phase when the presentation of fortification, mechanical blending is done for a time of 10 min. The stirrer was preheated before submerging into the soften, and is found around to a profundity of 2/3 tallness of the liquid metal from the base and keep running at a speed of 200 rpm.

The composite blend was filled changeless cast iron molds having breadth 12.5 mm and length of 125mm at a pouring temperature of. 750^0C.

D. Heat treatment

Solution heat treatments T6 type where composites have been exposed to solutionizing treatment at 530^0C for 1 h pursued by quenching in water. The quenched samples again exposed to artificial aging at 170^0C for 6 h followed via air cooled.

E. Mechanical characterization

The prepared composites were characterized by microscopic studies.

Specimens of 12 mm diameter and thickness of 10 mm were cut from the central portion of the casting for microstructure studies conducted using. The density of the samples were measured by Archimedes's method while theoretical density is computed by taking densities of 6061Al matrix and Hematite (Fe_2O_3) particles as 2.7 and 5.24g/cm3 respectively. To explore the mechanical characterization of the composites the hardness and tensile tests were completed utilizing Vickers Hardness testing machine and computerized uni-axial tensile testing machine. The Rockwell hardness estimations of the composites when expansion of Hematite (Fe_2O_3) particles was estimated with a load of 10N. The hardness esteemed detailed is the average values of 5 readings taken at different are s on the cleaned specimen. Similarly tensile tests were carried out before and after addition of Hematite (Fe_2O_3) particles and for each of the composite three tests were conducted and average value is repo rted.

Fig 1 .Graphical representation of Stir casting

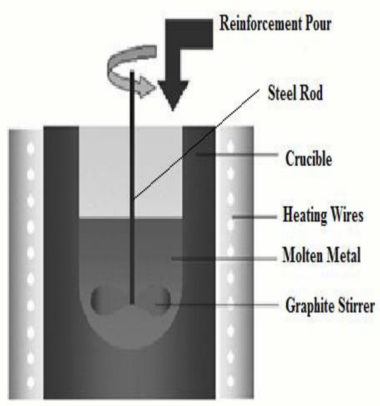


Fig 2. Resistance Furnace

Table 1: Shows the Chemical Composition of Al6061 alloy assessed using Atomic Absorption Spectrophotometer (Model AA-670, Varian, the Netherlands)

Elements	**Si**	**Fe**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Ti**	**Sn**	**Mg**	**Cr**	**Al**
Percentage	0.43	0.7	0.24	0.139	0.05	0.24	0.25	0.15	0.001	0.802	0.25	Balance

Material	**Physical properties**		**Thermal properties**	
Al6061	Melting point	660°C	Co-efficient of thermal expansion (20-100°C)	24.3µm/m°C
	Modulus of Elasticity	70-80GPa	Thermal Conductivity	173 W/mK
	Poisson's Ratio	0.33		
	Density	2.7g/cm^3		

Table 2: shows the physical and thermal properties of Al 6061

Table 3- Properties of Hematite (Fe_2O_3)

Properties	**Hematite (Fe_2O_3)**
Melting point	1524° C
Hardness (kg/mm^2)	1175
Density (g/cm^3)	5.24
Coefficient of thermal expansion (µm/m°C)	6.3
Fracture toughness (MPa-m$^{1/2}$)	3.5
Poisson's ratio	0.25
Color	red
Particle size	65Microns

Table 4: shows the complete details of the machines/equipments used in the present Investigation

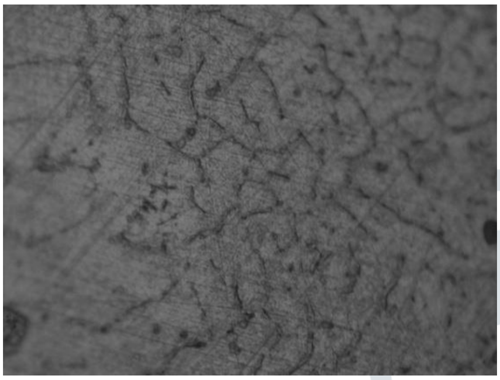
Sl. No	**Instrument/Equipment**	**Specification**
1	Digital Resistance Furnace	Capacity :5 Kg Operating Temp :1000°C Power rating :7.5 kw Heating Element :Sic
2	Electric Oven	Volts : 230 A.C Power rating : 3.5 K w Max. Temp : 300°C
3	Computerized Optical microscope	Name :Olympus Magnifications :10X,25X, 50X &100X
4	Computerized UTM	Machine model : TUE-400(C)
5	Rotating beam bending machine	Name : MFT 8D Max RPM :1000
6	Micro Vickers hardness Tester	Max Force : 10 to 50N Resolution : 0.0001 to 0.1micron Programmable time : 5-30 Sec

		Optical lens : 10X,25X,50X &100X
7	Electronic weighing machine	Capacity :2.2 Kg Accuracy :0.02 gm
8	Crucible	Crucible :Gr Capacity :1Kg
9	Mold or Die	Cast iron
10	Stirrer	Stainless steel coated with zirconium

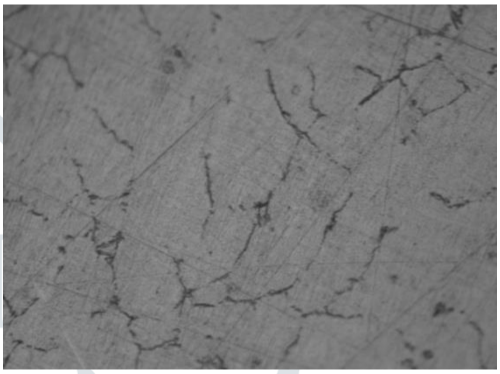
III. Results and Discussion

A. Microstructure studies

Fig.3 a-h shows microstructure of as cast 6061Al and 6061Al with 2 wt% (Fig. 4.1 c-d), 4 wt% (Fig. 4.1e-f) and 6 wt% (Fig. 4.1g-h) Hematite (Fe_2O_3) articulates.



(a)



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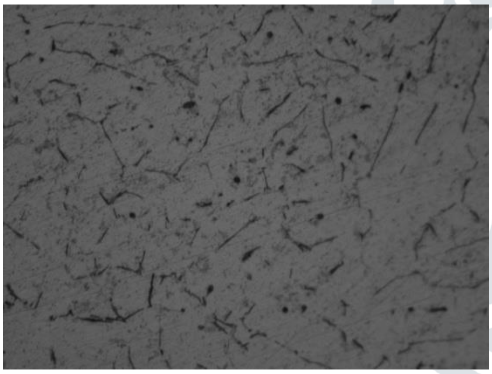

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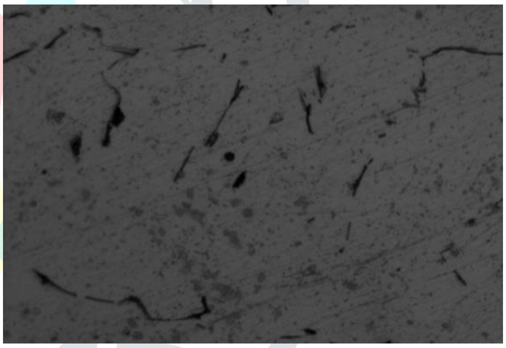

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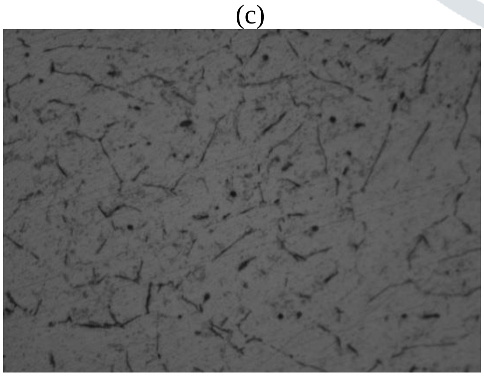

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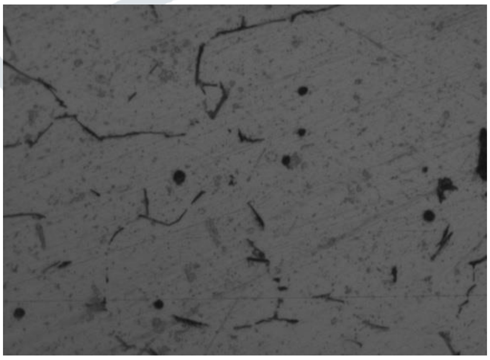

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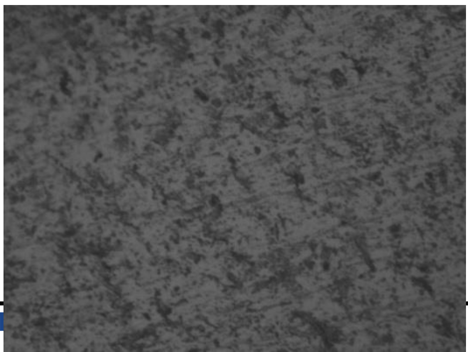

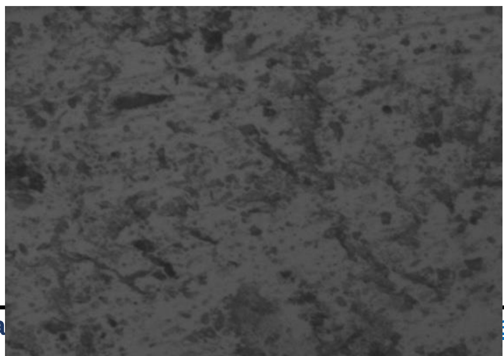

(g) (h)

Fig.3- **a-h** Showing the optical microphotographs of 6061Al with and without Fe_2O_3 particulates **(a-b)** without reinforcement**, (c-d**) with 2wt% of Fe_2O_3**, (e-f)** with 4wt% of Fe_2O_3 **& (g-h)** with 6wt% of Fe_2O_3

The microstructure of the readied composites contains essential. Al dendrites and eutectic silicon, while Hematite (Fe_2O_3) particles are isolated at between dendrite areas and in eutectic silicon. The mixing of softening when presenting particles has brought about breaking of dendrite molded structure into leveled with structure, it improves the wettability and joining of particles inside the liquefy and furthermore it causes to scatter the particles all the more Uniformly in the framework. Fig. 4.1(c-h) uncovers the conveyance of Hematite (Fe_2O_3) particles in various examples and it very well may be seen that there is genuinely uniform dissemination of particles and furthermore agglomeration of particles at few spots was seen in both the composites strengthened with 2wt%, 4wt% and 6wt% Hematite (Fe_2O_3).

The microphotographs additionally show that the Hematite (Fe2O3) particles have the inclination to isolate and bunch at between dendrite areas which are encompassed by eutectic silicon (Fig.4.1.c-h). Further, the micrographs demonstrate that grain size of the strengthened composite (Fig.4.1.a-h) is littler than the compound without alumina particles (Fig. 4.1 a-b) since Hematite (Fe2O3) particles added to dissolve likewise go about heterogeneous nucleating sites during solidification.

B. Hardness measurements

Fig 4 Shows the comparison of hardness value before and after aging treatment. The Vickers hardness were measured on the polished samples using diamond cone indenter with a load of 10N and the value reported is average of the readings taken at different locations. A significant increase in hardness of the alloy matrix can be seen with addition of Hematite (Fe_2O_3) particles. Higher value of hardness is clear indication of the fact that the presences of particulates in the matrix have improved the overall hardness of the composites. This is true due to the fact that aluminum is a soft material and the reinforced particle especially ceramics material being hard, contributes positively to the hardness of the composites. The presence of stiffer and harder Hematite (Fe_2O_3) reinforcement leads to the increase in constraint to plastic deformation of the matrix during the hardness test. Thus increase of hardness of composites could be attributed to the relatively high hardness of Hematite (Fe_2O_3) itself.

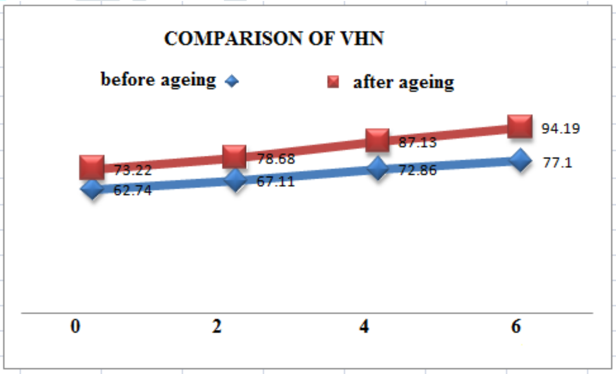

Fig. 4 Graph showing the comparison of hardness number before and after ageing

C. Tensile strength

Three specimens were used for each test and average value is reported. The tensile properties, such as, tensile strength, yield strength and % elongation were extracted from the stress-strain curves and are represented in Table 5 and Fig 5, Fig 6 and Fig 7., it is clear that the tensile strength, yield strength and ductility increases with increase in amount of reinforcement before heat treatment. Increase in strength is possibly due to the thermal mismatch between the metallic matrix and the reinforcement, which is a major mechanism for increasing the dislocation density of the matrix and therefore, increasing the composite strength. When compared with heat treatment, heat treated specimen's shows higher in strength and ductility but decrease in its ductility. It is obvious that plastic deformation of the mixed soft metal matrix and the non-deformable reinforcement is more difficult than the base metal itself. As a result, the ductility of the composite drops down when compared to that of untreated specimens.

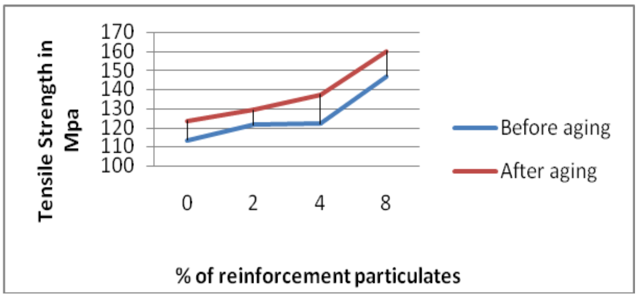

Fig. 5 Graph showing the comparison of Tensile strength before and after ageing

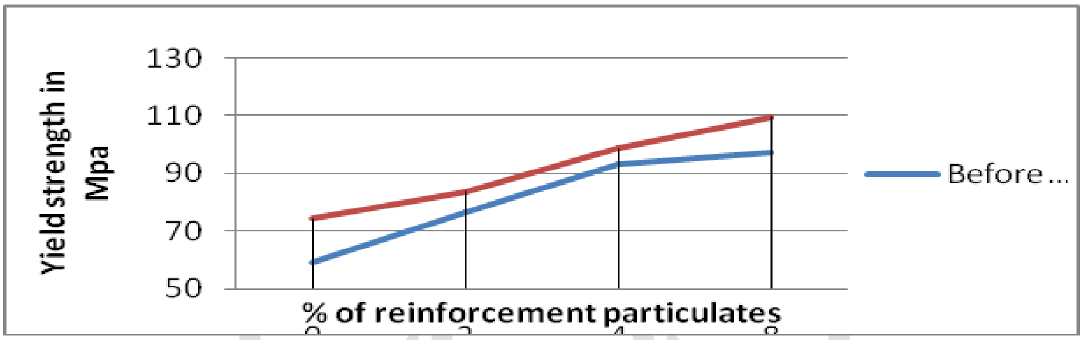

Fig. 6 Graph showing the comparison of Yield strength before and after ageing

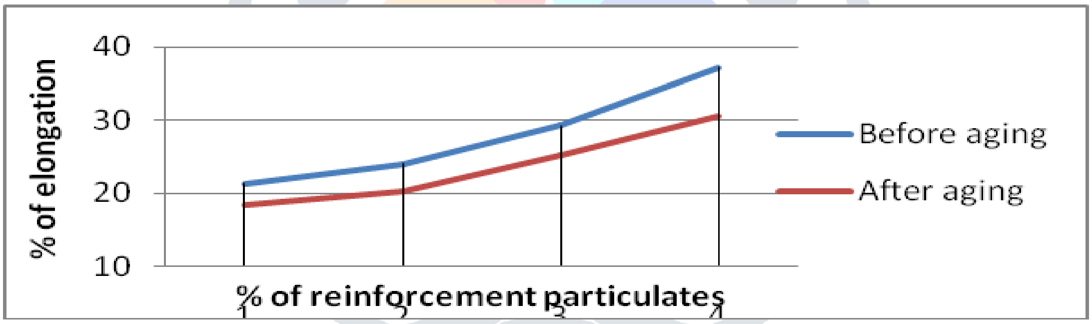

Fig. 7 Graph showing the comparison of % of elongation before and after ageing

Table 5: Showing the tensile test results of as cast 6061Al, with addition of 2, 4 and 6 wt% of Hematite (Fe_2O_3) particulates to 6061Al before and after ageing.

Sl. No	% of Reinforcement	Tensile strength (MPa)		Yield strength (MPa)		% of elongation (MPa)	
		Before aging	After aging	Before aging	After aging	Before aging	After aging
1	AL6061	113.47	123.49	59	74.19	21.30	18.36
2	AL6061+2% Fe_2O_3	121.40	129.10	76.57	83.79	24.02	20.20
3	AL6061+4% Fe_2O_3	122	137.15	93.07	98.56	29.30	25.21
4	AL6061+6% Fe_2O_3	147	160	97.15	109.55	37.13	30.59

IV. CONCLUSIONS

The present work on Studies of mechanical and fatigue properties of Al 6061- Hematite (Fe2O3) metal matrix composite with precipitation hardening and without precipitation hardening has led to following conclusions:

1. Aluminium based metal matrix composites have been successfully fabricated by Melt stirring

method by three step addition of reinforcement combined with preheating of particulates.

2. The optical microphotographs of composites produced by Melt stirring method shows fairly uniform distribution of Hematite (Fe_2O_3) particulates in the Al6061 metal matrix. The microstructure of the composites contained the primary a-Al dendrites and eutectic silicon with Hematite (Fe_2O_3) particles separated at inter dendrite regions.
3. Al6061- Hematite (Fe_2O_3) composites have shown higher hardness when compared to the hardness of Al6061-alloy. Also hardness of composites increases with increasing wt% of reinforcement.
4. The hardness of composites after subjecting them to the heat treatment also increases with increasing wt% of reinforcement.
5. Strength of prepared composites both tensile and yield was higher in case of composites. Further, with increasing wt% of Hematite (Fe_2O_3), improvements in tensile strength and yield strength of the aged composites

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