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Investigating the Influence of Precipitation Hardening and Characterization of Aluminium Alloy Composite Material

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Metal matrix composites (MMCs) have gained importance in all the field of engineering application. Aluminium has a favorable strength to weight ratio, and compared to other materials used in bicycle and automotive industries. In this project work, the aging behaviour at Al6013-SiC composite is compared with pure alloy of Al 6013and characteristics investigation was performed. The composites were fabricated by using stir casting method. Aluminium 6013 alloy as matrix material and 15% SiC as reinforcing material. The mechanical properties of aluminium alloys are highly improved by adding SiC particles as reinforcement. Prepared Al6013-SiC composite were subjected to precipitation hardening. From the investigation the precipitation hardening of composite materials has been subjected to find the mechanical properties such as hardness, tensile and wear test. The experimental results showed that hardness, tensile strength, wear resistance were increased while aging behavior of Al6013-SiC varied.

Keywords: Al6013 alloy, Silicon Carbide, stir casting, precipitation hardening, mechanical properties.

I. INTRODUCTION

Composite materials are new generation materials to meet the demands of rapid growth of technological changes of the industry. Composites are engineering materials made from two or more constituents' materials. One constituent is called matrix phase. Other is called reinforcing phase. Reinforcing phase is embedded in the matrix to give desired characteristic. Non-continuous phase called the reinforcement. MMCs are made by dispersing a reinforcing material into a metal matrix. The advantages metal matrix composites over the polymer matrix composites include are higher operating temperature, do not absorb moisture, better electrical and thermal conductivity.

The super alloys, as well as alloys of aluminum, titanium, and copper are employed as matrix materials. The reinforcement may be in the form of particulates, continuous and discontinuous fibers. Aluminium alloy 6013 is a new medium strength alloy that provides improved formability and corrosion resistance for use in aerospace applications. Al 6013 alloy has (aluminum-magnesium-silicon-copper) yield Strengths 12% higher than Al 2024.Uses for 6013 include primary structural applications including fuselage panels, Bicycle frame and mobile phone application. Silicon carbide is ceramic material maintain their strength over high temperatures, approaching 1600°C with no strength loss.

Stir casting is a liquid state method of composite materials fabrication in which a dispersed (secondary phase) is mixed with a molten matrix metal by means of mechanical stirring followed by its solidification. Precipitation hardening refers to the enhanced strength resulting from the presence of small finely dispersed phase particles, commonly called precipitates within the original phase matrix. The precipitation hardening of composite materials has been subjected to find the mechanical properties such as hardness, tensile and wear test. The experimental results showed that hardness, tensile strength, wear resistance were increased while aging behaviour of Al6013-SiC varied.

K. Mahadevan et al., [1] investigated the effect of precipitation hardening parameters on the fatigue strength of AA 6061-SiC composite. SupriyaNandy et al., [5] researched on the Mechanical Properties of 6063 Al Alloy by precipitation hardening process. B.M. Viswanatha et al., [7] concluded the dry Sliding Wear Behaviour of Al-MMC for Disc Brake under aging process. V.Vembu et al., [8] effectively used RSM method to optimization heat treatment for tensile properties of 8011 Al/15% SiC metal matrix composite.

II. EXPERIMENTAL WORK

A. Stir Casting

The three compositions C1, C2, C3 (85 wt % of Al 6013, 15 wt % of SiC) were fabricated by stir casting method. The conventional experimental setup of stir casting essentially consists of an electric furnace and a mechanical stirrer. The electric furnace carries a crucible of capacity 2kg. The maximum operating temperature of the furnace is 1000ºC. The current rating of furnace is single phase 230V AC, 50Hz. The metal scraps are poured into the furnace and heated to a temperature just above its liquidus temperature to make it in the form of semi liquid state (around 600ºC). The mixing of aluminium alloy is done manually for uniformity. Then the reinforcement powder that is preheated to a temperature of 250°C is added to semi liquid aluminium alloy in the furnace. Again reheating of the aluminum matrix composite is done until it reaches complete liquid state. Meanwhile Magnesium is added to the molten metal to remove the soluble gases present in liquid state metal and it will also enhance the wettability. During this reheating process stirring is done by means of a mechanical stirrer which rotates at a speed of 500 rpm with 15min.The aluminium composite material reaches completely liquid state at the temperature of about 800°C as the melting point of aluminium is 700ºC. Thus the completely melted aluminium metal matrix composite is poured into the permanent mould to produce the required specimen. Figure 1 showed that Stir casting setup.

Figure 1 Stir Casting Setup

B. Precipitation Hardening

The heat treatments were conducted in an electrical resistance furnace. The temperature of solid solution treatment was (560±2) °C. All samples were held at 560°C for different solutionzing time 1, 2, 3 hrs respectively. The second step is quenching. Quenching is simply cooling the sample rapidly to a lower temperature, usually room temperature and the cooling medium is usually water at room temperature. The rationale behind the quenching process is to preserve the uniform solid solution structure of the alloy below the homogenization temperature. Then aging artificially at room temperature (T6) at different temperature 150°C, 170°C, 200°C (T6) and different aging time 3, 5, 7 hrs. Table 1 showed that different level of aging parameter.

Table 1 Different level of Aging Parameter

Sample No	Al 6013	SiC	Solutionzing Time (hrs)	Aging Temp (ºC)	Aging Time (hrs)
C1 = (C11 & C12)	85	15	1	150	3
C2 = (C21 & C22)	85	15	3	170	5
C3 = (C31 & C32)	85	15	5	200	7

C. Tensile Test

Test specimens were prepared according to ASTM E8 standards, each specimen having 20mm in diameter and 50mm gauge length. The specimen was loaded in Universal Testing Machine until the failure of the specimen occurs. Tests were conducted on composites of different combinations of aging parameter and ultimate tensile strength and yield strength were measured. Figure 2 shows that some tensile test specimen after testing.

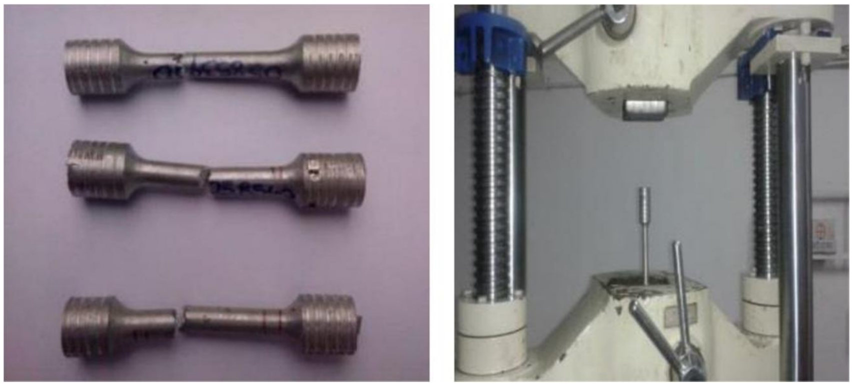

Figure 2 Tensile test specimens

D. Hardness Test

The hardness test specimens were prepared as per ASTM E10-15 test standards. The Brinell hardness test method consists of indenting the test material with a 5 mm diameter ball subjected to a load of 250 kg. The full load is applied for 1 minute. For harness results, test was repeated three times to obtain a precise average value. Figure 3 showed the Brinell hardness apparatus and test specimen. Figure 3 showed that Brinell hardness apparatus and test specimen.

Figure 3 Brinell hardness Tested Specimens

E. Wear Test

Pin on disc wear testing is a commonly used technique for investigating abrasive wear of the material. As the name implies that the apparatus consist of a “pin” in contact with a rotating disc. Either the pin or disc can be the test piece of interest. The contact surface of the pin may be flat, spherical or indeed of any convenient geometry, including that of actual wear components. In a typical Pin on disc experiment, the coefficient of friction is continuously monitored as wear occurs and the material removed is determined by weighing and / or measuring the profile of the resulting wear track. Figure 4 showed that pin on disc apparatus. The wear test was conducted according to ASTM-G99 test standards. Three different compositions of wear specimens are shown in figure 4.

Figure 4 Brinell hardness Tested Specimens

III. RESULTS AND DISCUSSION

Table 2 Mechanical properties of different aging parameter samples

Aging Parameter	No of Samples	Tensile strength (Mpa)	Yield strength (Mpa)	Hardness (BHN)	Wear rate (*10^{-5} mm3/m)
C1	C11	365	311	131	4.143
	C12	352	323	138	3.122
C2	C21	378	338	152	3.187
	C22	387	345	144	3.067
C3	C31	374	328	144	3.288
	C32	365	332	137	3.506

A. Tensile and Yield strength

Aging behavior (C2) has more tensile and yield strength than compared to aging behaviors like C1 and C3. From this diagram the most ultimate strength is 387Mpa and corresponding most value of yield strength is 345Mpa. Aging parameter C2 (solutionzing time-3hrs, aging temperature-170°C, aging hours-5 hrs) is more influence of the tensile and yield strength than the age behaviour of C1 and C3.

B. Hardness

Aging behaviour (C2) has more hardness than compared to aging behaviors are C1 and C3. From this diagram the most hardness value is 152 BHN. Aging parameter C2 (solutionzing time-3hrs, aging temperature-170°C, aging hours-5 hrs.) is more influence of the hardness than the age behaviour of C1 and C3.Aging parameter (C2) of tensile strength is 9.21%, 5.26% increased compare to aging parameter (C1) and aging parameter (C3).

C. Wear Rate

Aging behaviour (C2) has more wear resistance(less amount of wear rate) than compared to aging behaviors are C1 and C2. From this diagram the most wear rate is 4.143*10^{-5}(mm3/m) in the specimen (C1). Aging parameter C2 (solutionzing time-3hrs, aging temperature-170°C, aging hours-5hrs) is more influence of the wear resistance than the age behaviour of C1 and C3.because hardness value of specimen (C2) higher than specimen C1 and C3.

D. Comparison between Aging parameter and Mechanical behaviour

It is observed that optimum ultimate tensile strength is 387Mpa, the corresponding aging parameters are (solutionzing time-3hrs, aging temperature-170°C, aging hours-5 hrs).the optimum level of tensile strength. Compared to normal Al 6013 alloy, tensile strength is 7.23% more than pure Al 6013 alloy. Optimum yield strength is 345Mpa, the corresponding aging parameters are (solutionzing time-3hrs, aging temperature-170°C, aging hours-5 hrs).the optimum level of yield strength compared to normal Al 6013 alloy, and yield strength is 8.11% more than pure Al 6013 alloy.

It observed that optimum wear resistance is 3.187 *10^{-5} (mm^3/m) the corresponding aging parameters are (solutionzing time-3hrs, aging temperature-170°C, aging hours-5 hrs). It observed that optimum hardness is 152 BHN, the corresponding aging parameters are (solutionzing time-3hrs, aging temperature-170°C, and aging hours-5 hrs.).The optimum level of hardness compared to normal Al 6013 alloy, hardness is 14.47% more than pure Al 6013 alloy. Optimum mechanical properties obtained from peak aging (C2) condition. Because, amount of resistance the dislocation atom movement in peak aging condition by precipitation particle formation. Corresponding lowest mechanical properties obtained from under aging (C1) over aging (C3) condition. Because, in high temperature condition material has loose some properties. In low temperature condition could not established effective mechanical properties.

IV. CONCLUSION

A. Composite material of Al 6013 reinforced with SiC was successfully fabricated by using stir casting method. Precipitation hardening heat treatment was successfully conducted by different solutionzing hours, aging temperature, aging hours. Micrographs image of the specimens aged at different temperatures and times were taken.

B. Solutionzing time-1hrs, aging temperature-150°C, aging hours-3hrs (C1) had maximum wear rate and lowest tensile strength rather than aging parameters of specimens C2 and C3.Solutionzing time-3hrs, aging temperature-170°C, aging hours-5hrs had minimum wear rate and better tensile strength rather than the pure alloy of Al 6013

C. Yield strength and hardness were 8.11% and 14.47% increased compare to pure alloy of Al 6013 by adding silicon carbide content and precipitation hardening process in the aging parameter (C2) of specimen

D. Also tensile strength was 7.23% increased compare to pure alloy of Al 6013 by adding silicon carbide content and precipitation hardening process in the aging parameter (C2) of specimen

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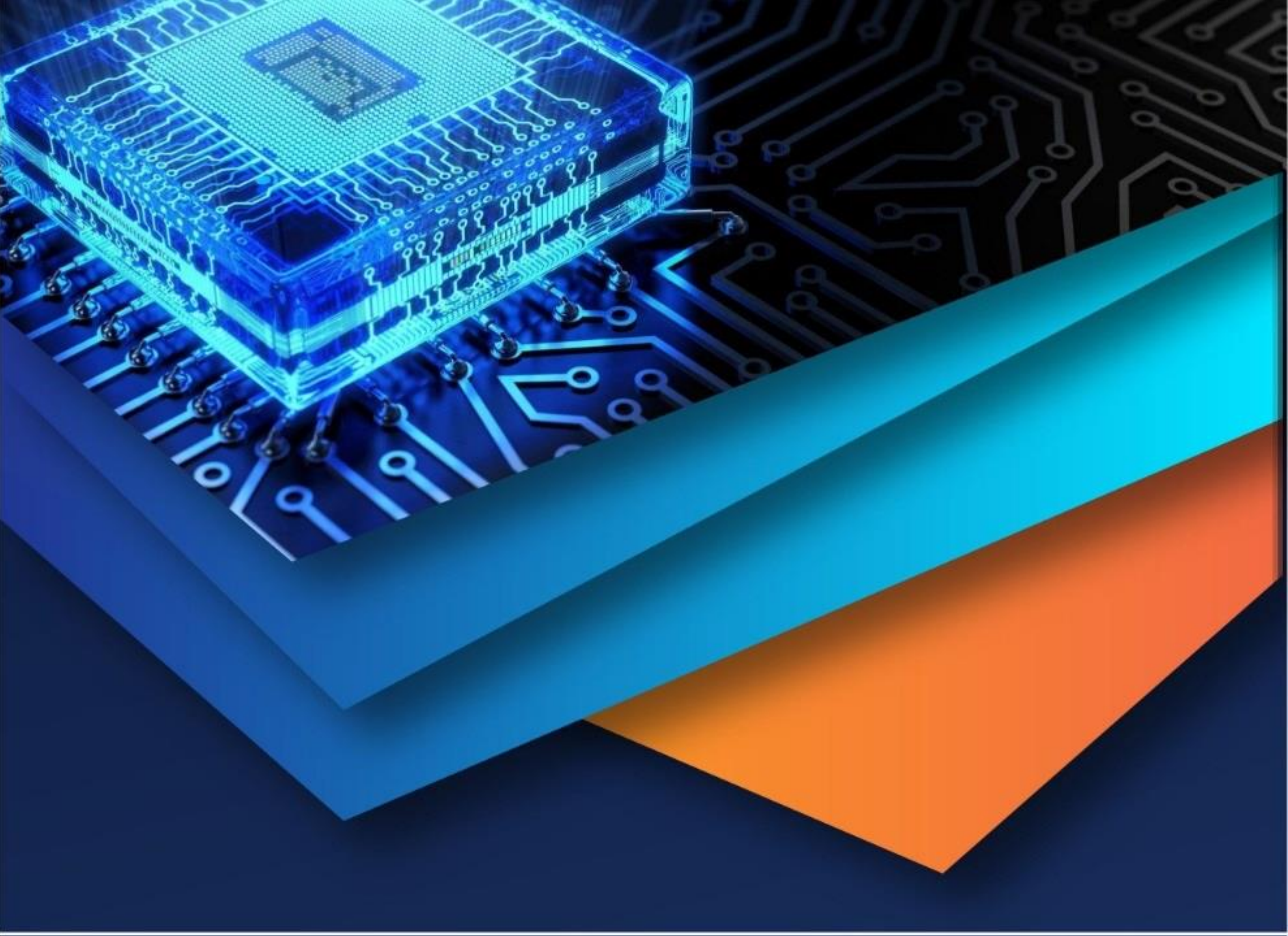

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