EFFECT OF AGEING ON MICROSTRUCTURE AND HARDNESS OF STIR CAST Al7075/SiC MMC'S

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ABSTRACT

Aluminum MMC's are preferred in aerospace, automotive and marine application due to their improved properties like high strength to weight ratio, high temperature property, good wear resistance etc. In this paper an attempt has been made to synthesize MMC's using Al7075 as matrix material reinforced with ceramic SiC of particle size of 125µm by stir casting technique. Reinforcement particles were preheated to a temperature of 1100^oC and then dispersed in steps of three into the vortex of molten Al7075 alloy to improve wettability and distribution. The Al7075/SiC MMC'S has been subjected to heat treatments to study the influence of artificially ageing at 150, 175, 200^oC for 6, 10, 12, 15 h on microstructure, grain boundary formation, precipitates and hardness. Microstructural characterization for the heat treated condition was carried out paying special emphasis to the distribution of SiC particle in Al matrix and interface bonding between them.

Keyword: - *Metal matrix composite, SiC, 7075 Al, microstructure, heat treatment, ageing, XRD, hardness*

1. INTRODUCION

Addition of SiCp (Silicon Carbide particulates) to Aluminum alloys result in an increase of modulus, and also be accompanied by an increase in yield stress depending upon the alloy composition, heat treatment, and manufacturing method. It also helps in increasing wear resistance, corrosion and fatigue crack initiation in cooperation to the performance of the matrix alloy alone. It has been reported that addition of SiCp reinforcement to Aluminum alloys usually lowers the fracture toughness [1] Aluminum-silicon carbide MMC's has low density, high temperature strength, hardness and stiffness, high fatigue strength and wear resistance as compared to the monolithic materials. Aluminum alloy with discontinuous ceramic reinforced MMC's is currently replacing conventional materials in various automotive, aerospace, and automobile industries [2].

Stir casting is attractive because it is a conventional metal processing route based method hence it is the most economical among other available routes for MMC's production, and for very large sized components to be fabricated. To obtain a suitable dispersion and to avoid the attack of SiC by liquid aluminum, silicon and magnesium are used as it lowers the melting point of the alloy and decreases the contact angle between the solid and the liquid, thus improves wettability. [3].The precipitation-strengthening (hardening) process is used to increase the strength of Aluminum and other metal alloys. The object of hardening is to create a heat treated alloy with dense and fine dispersion of precipitates in a matrix of deformable metal [4].

Number of factors are there which influence composite Materials properties and these factors are complex and interrelated to each other. Increase in processing temperature with different holding time. Results in altering the matrix composition and also modifies the kinetics of reaction between matrix and reinforcement. When processing temperature increases, the fracture strength increases continuously, despite the fact that silicon concentrations at the interfaces were increased. The hardness values were measured at the interface. The hardness values increases with increasing processing temperature due to better wettability and good interface between the SiC and aluminum matrix at higher temperatures [5].

Aluminum MMC's represent changes in mechanical and microstructure property with the ageing and cooling treatment. In this paper we have analyzed the SiC distribution, dissolution and embed behavior with aluminum matrix it causes changes in it hardness property. Heat treatment gives formation of phases and intermettalic, which add other effect into the composite and changes its property according to the phase present in composite.

2. EXPERIMENTAL PROCEDURE

2.1 Stir Casting

In this paper Al7075 having the theoretic density of 2760 kg/m3 was used as a matrix material. The chemical composition of matrix material is given in Table 1. SiC particulates with an average size of 25 micron were used as reinforcement materials. Magnesium is used as a wetting agent to improve wettability between matrix and the reinforcements during production of the hybrid composites.

Table-1: Composition of Al-SiC MMC'S

Metal	Cu	Mg	Zn	Cr	Al	SiC
Alloy (%)	1.6	2.5	5.6	0.3	Remainder	Nil
Composite (%)	1.6	2.5	5.6	0.3	Remainder	6

Pretreatment of Material and crucible

Aluminum alloy was first preheated at 450°C for 2 hours before melting and SiC particulates were preheated at 1100°C for 1 hour 30 minutes to improve the wetness properties by removing the absorbed hydroxide and other gases and to avoid the reaction between SiCp and Al matrix. Then SiCp added incrementally into the molten Al matrix at sequential steps. Crucible and stirrer preheated 300-400^{o}C.

Preparation of composites

The furnace temperature was first raised above the melting temperature that is, 750°C to melt the matrix completely and then it allowed to cool down just below the melting temperature to maintain semi-solid state slurry. Al liquid metal stirred at 900 rpm for 1 min until vortex formed. The composite slurry was then reheated to a fully liquid state and mechanical mixing was carried out for 20 mins at 750rpm average stirring speed, the preheated SiC particles were added at this stage and mixed mechanically with addition of magnesium at the rate of 2% after each 5 min.
Magnesium also added with the SiC in equally proportion of 0.5%. Before and after introduction of reinforcement, at every stage mechanical stirring is carried out for a period of 5 min Amount of reinforcement required is calculated and then introduced into the molten metal at the 3 stages rather than introducing all at once. The stirrer was preheated before immersing into the melt, and is located approximately to a 2/3 depth of the molten metal from the bottom with having speed of 200 rpm. After 20 mins of continue stirring hold the molten composite for 10 min at 700^{o}C and stir it again for 5 mins at 1100rpm. Mixture of composite poured into cast iron mould having diameter of 10mm and 150mm length at a pouring temperature of 750^{o}C.At the final stage mixing, the furnace temperature is maintained between 760 ± 10°C and the temperature was controlled at 740°C.

2.2 Solutionizing and Artificial Aging

The specimens of Al-Si-SiC composite were heat treated to compare the properties in aged and stir cast condition. There were three stages involved in the heat treatment.
i) Solutionising: The specimens were heated to a temperature of 490 ± 5^{o}C for 8 hours until the alloy solute elements are completely dissolved in the Al solid solution.

ii) Quenching: the solution treated specimens were rapidly cooled into oil to prevent the precipitation of the solute elements and to obtain a super saturated solid solution and
iii) Artificial aging: To improve the strength and hardness of the material the specimens were reheated to 150^{o}C /175^{o}C/200^{o}C for 6,10,12,15 hours each and then allowed to cool in the still air.

2.3 Scanning Electron Microscope

SEM photographs were obtained using Scanning Electron Microscope (VEGA3 TESCAN) with energy dispersive X-ray analyser (EDX) was used to study microstructure of the hybrid composites. The samples for SEM were ground by means of abrasive papers followed by rotating disk cloth polishing. Keller's reagent (95 ml water, 2.5 ml HNO_3, 1.5 ml HCl, 1.0 ml HF), very popular general purpose reagent for Al and Al alloys, was used as an etching agent.

2.4 XRD Characterization

The XRD analysis is conducted for phase detection present in the aluminum SiC composite were studied by X-ray diffraction using a PHILIPS X-Pert High Score program system, with Cu - Kα radiation (λ=1.54 A^{o}). The phases formed are identified with the ICDD database by insidious comparison of the recorded diffraction peaks.

2.5 Hardness Test

To investigate the mechanical behavior of the composites the hardness were carried out using Rockwell hardness test. The Rockwell hardness values of the composites before and after addition of SiC particles were measured with a load of 100kgf using 1/16 Ball indenter for testing the samples for hardness (Meta test instrument Pvt. Ltd, Model:MRS). The hardness value reported is the average value of 10 readings taken at various locations on the polished specimen.

3. RESULTS AND DISCUSSIONS

3.1 SEM Images of 7075Al-SiC MMC'S

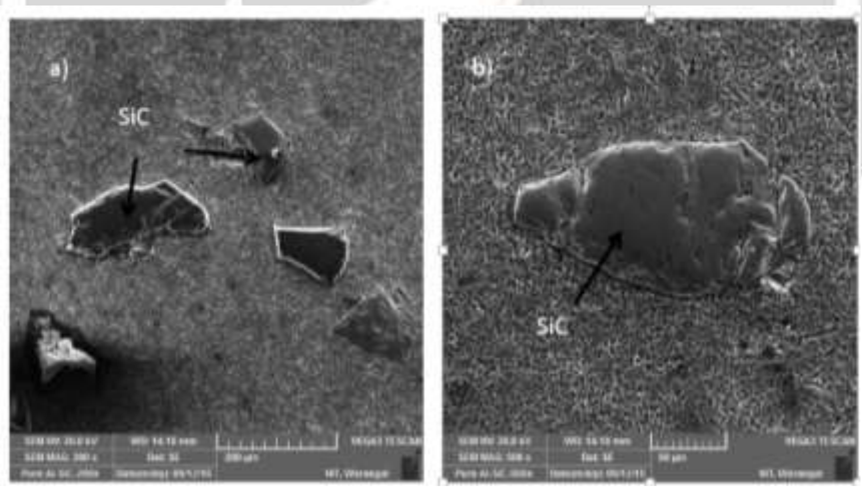

Fig-1: SEM Images of 7075Al-6%SiC Stir Cast composite (a) 200X, (b) 500X

Microstructure of 7075Al-6%SiC Stir cast composite shown in fig.1 gives uniformly distributed particle of SiC. SiC particle are easily visible with the Al matrix grain boundary. Without heat treated sample not showing the presence of any phase agglomeration of SiC particle.

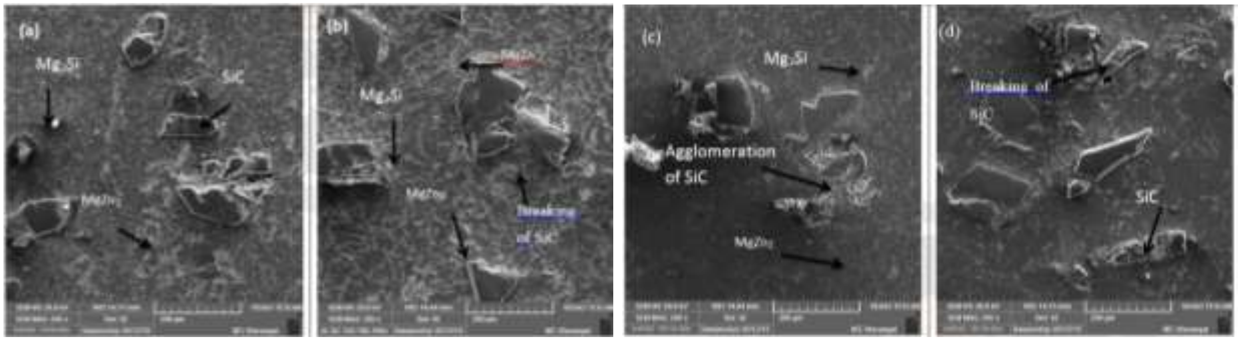

Fig-2: SEM images of Solutionized at 495^{o}C and Aged sample at 150^{o}C for (a) 6, (b) 10, (c) 12 and (d) 15h

From fig.2 (a), (b), (c) & (d) the microstructural changes developed at 150^{o}C for 6hr Solutionising we visible grain boundary, and less no. of silica particle. At higher time 15hr Solutionising temperature grain boundary are not clearly visible with uniform distribution of silicon carbide.

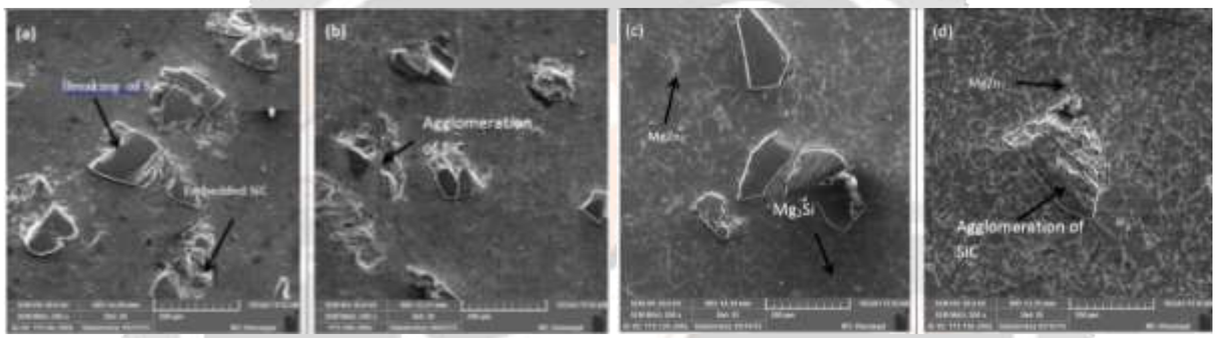

Fig-3: SEM images of Solutionized at 495^{o}C and Aged sample at 175^{o}C for (a) 6, (b) 10, (c) 12 and (d) 15h

The phases responsible for hardening are dissolved during higher aging temperature and time higher aging time preferred to agglomeration, embedation and breaking of SiC particle which causes decrease in Hardness, Mg_2Si amount decreases at higher time and coarsening of phases occurring with increasing time.

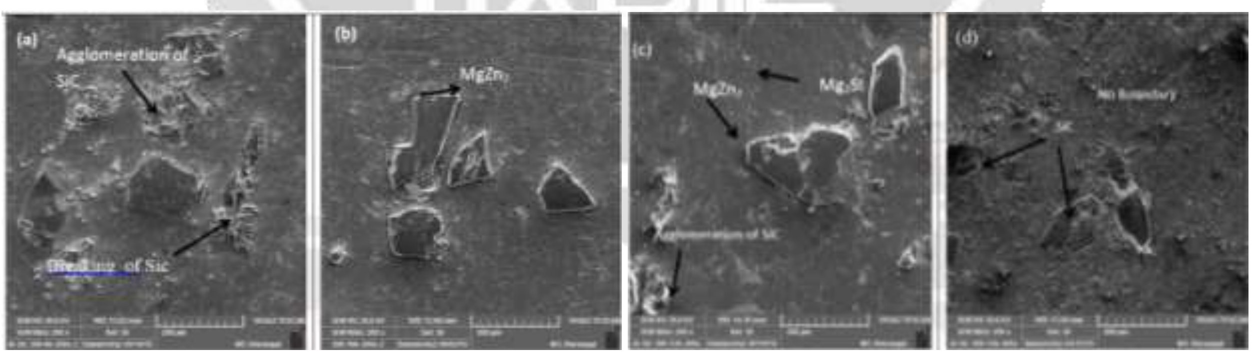

Fig-4: SEM images of Solutionized at 495^{o}C and Aged sample at 200^{o}C for (a) 6, (b) 10, (c) 12 and (d) 15h

At lower aging temperature grain boundary are present with MgZn phase but with higher temperature it is getting dissolve and disappear from the matrix. At high temperature aging, in some instances, cracking of the matrix is observed this may be due to the expansion of gases which entrap into the coarsening matrix or coarsening of the phases.

3.2 XRD Analysis of Al7075/SiC

XRD analysis of Al7075-SiC Solutionized and aged sample were carried out at different temperature and time and the results are shown in Fig.5, 6 and 7. These results indicate the Al, SiC and other phases distribution and their intensity present in stir casted Al7075-SiC composite.

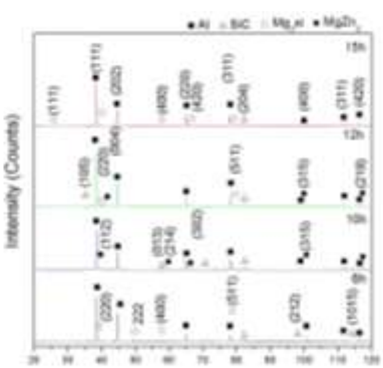

Fig.-5: Aged at 150^{o}C for 6, 10, 12 and 15h

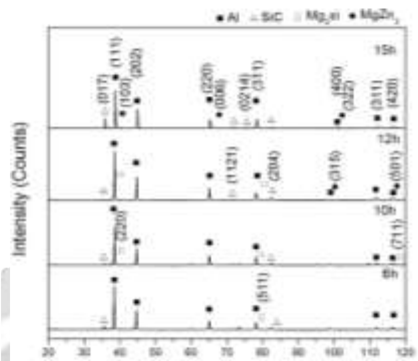

Fig.-6: Aged at 175^{o}C for 6, 10, 12 and 15h

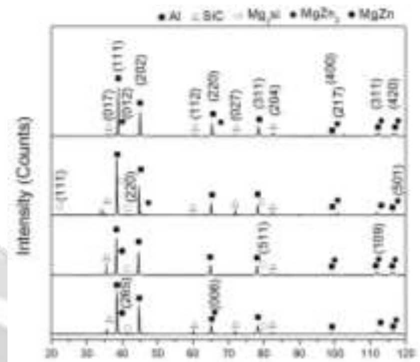

Fig.-7: Aged at 200^{o}C for 6, 10, 12 and 15h

At 150^{o}C aging temperature we observed that Al, SiC, $MgZn_2$ and Mg_2Si are present. At 6h phase's peak are more as compared to 15h at all temperature. At higher time phase peaks are getting decrases.at 175^{o}C phases are less as compared to 150^{o}C at all aging time. We observed that SiC is uniformly distributed in Al matrix. All peaks are represented with their hkl value in vertically bracket.

3.3 Rockwell hardness (HRB) value of aged sample

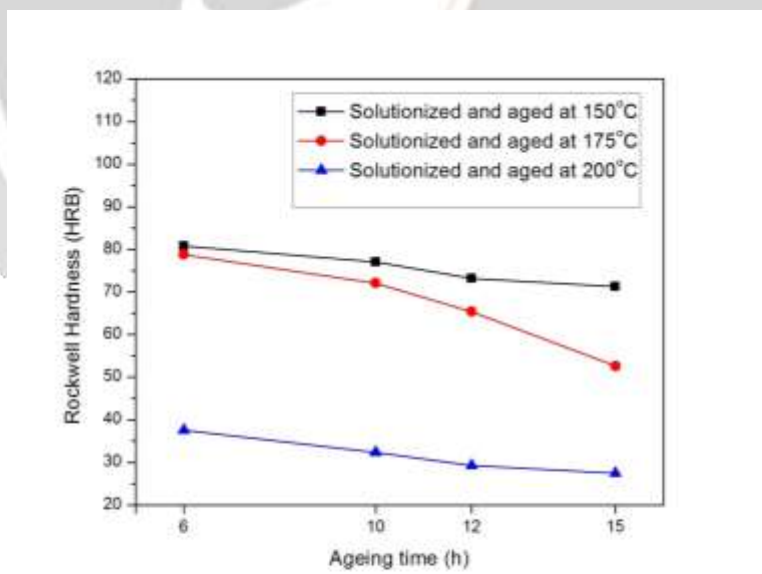

Fig-8: Effect of ageing time and temperature on Hardness of the 7075 Al-SiC MMC'S Solutionized at 495°C for 6h and aged**.**

Hardness of aged sample at 150^{o}C and 6 hours found to be 83.33 HRB which is less than the base 7075 alloy matrix due to effect of aging. We observed that with temperature and time hardness goes on decreasing. Aging at higher temperature in turn have coarsening effect of the precipitates which results into poor hardness value. We also observed that the phases responsible for hardening are dissolved during higher aging temperature and time causes to decrease in hardness.

4. CONCLUSIONS

1. Al7075-SiC gives $MgZn_2$ filigree and Mg_2Si phases with Solutionized and aged condition at 150^{o}C 6h nucleation occur and getting coarser particle with higher aging time.$MgZn_2$ this phases are along the grain boundary in continuous manner.
2. During heat treatment the interface between SiC particle and Al matrix acts as nucleating agent for the intermetallic precipitates, thus large amount of precipitates of relatively coarser size are observed at the interfacial region.
3. Hardness decreases with time and temperature because of coarsening of phase and discontinuous manner along the grain boundary and agglomeration of SiC particle. At 150^{o}C 6 h give higher hardness because of good interface between SiC and aluminum matrix, $MgZn_2$ continuous manner in fine particle.
4. At 200^{o}C and 12h aged condition we get less hardness value grain due to grain boundary dissolution and cracking due to coming out of gases which entrapped during casting.
5. Hardness value at temperature 175^{o}C as compared to 150^{o}C not decreased that much amount which is decreased at 200^{O}C due to good SiC particle interface and not much dissolution of phases.

5. REFERENCES

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