Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 1, No.3, January : 2025

SEMI-SOLID PROCESSED A356 METAL MATRIX COMPOSITE USING POLYMER INJECTION PYROLYSIS (PIP) APPROACH

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ABSTRACT

This project investigates the age-hardening behavior of Aluminium-based in-situ metal matrix composites (MMCs) reinforced with 2.5 vol% SiOC ceramic particles. A356 alloy was melted using the stir casting method, and polysiloxane (containing poly-hydromethylsiloxane, PHMS) was added to the molten alloy. The polymer underwent in-situ pyrolysis, forming SiOC ceramic particles dispersed within the alloy. Both the base material and the composite underwent solution treatment at 540°C for 6 hours, followed by water quenching. Aging treatments were carried out at 150°C, 250°C, and 350°C for 3 to 15 hours. Microstructural analysis revealed uniform particle distribution and grain refinement due to the SiOC particles acting as nucleation sites. The hardness of the composite was higher than the base material in both solution-treated and aged conditions. Additionally, the presence of SiOC particles reduced the aging time required to reach peak hardness, indicating their role in enhancing the material's mechanical properties.keyword : Aluminium-based composites, In-situ metal matrix composites (MMCs),SiOC ceramic particles , A356 alloy ,Stir casting method , Polysiloxane precursor , Poly-hydromethylsiloxane (PHMS) , In-situ pyrolysis, Age-hardening behavior.

INTRODUCTION

Many of our modern technologies require a mixture of properties that cannot be met by conventional metal alloys. The main challenge in the development and processing of engineering materials is to control the microstructure, mechanical properties, and cost of the product. Therefore, it led to the development of composite materials. Composite materials can achieve tailorable properties. Among the different types of composites, Metal Matrix Composites (MMCs) are the most widely used in industries. The size and shape of the reinforcements play a vital role in determining the properties of composite materials. (3) The conventional stir-casting method is not suitable for adding fine- sized ceramic particles due to poor wettability, weak interface, and non-uniform dispersion. Therefore, to overcome this problem, polymer-derived In-situ Metal Matrix Composite by Stir Casting can be done. Aluminium Matrix Composites (AMCs) are widely used owing to their high specific strength and modulus. This Nano-sized reinforcement can effectively be achieved by an in- situ process and results in finer particle size, clean interface, and good wettability between the reinforcement and the matrix material. Here the reinforcement is by polymer precursor, which on pyrolysis gives the hard ceramic particles hence it is named Polymer Derived Ceramics (PDC). The main issue associated with the fabrication of metal matrix composite is to achieve uniform distribution of Nano-sized ceramic particles by bulk manufacturing processes. In-situ processing can be done to enhance the uniform distribution of reinforcements in the matrix. A356 alloys are age hardenable and widely used in both cast and wrought forms. It can be noted that reinforcing ceramic particles into the matrix enhances the mechanical properties by dispersion hardening mechanism and this AMMC finds application in automobile and aerospace industries. Generally, heat treatments are conducted on the materials to improve their properties so that the longevity of the materials may increase. The strengthening of these alloys is based on the precipitation-hardening process. Henceforth the present investigation is conducted in fabricating A356/2.5 vol% SiOC and also to observe the change in microstructure and hardness of the composites after age-hardening.(6

Literature

Aluminium Matrix Composites Al alloys and Al-matrix composites (AMCs) have received much attention for automobile, aerospace, aircraft, defence, and structural applications due to their high specific strength and specific stiffness, higher hardness and wear resistance, and good elevated temperature resistance. Metal Matrix Composites (MMCs) can be synthesized mainly in solid-state processing and liquid state processing. Composites processed by these techniques suffer from various problems like thermodynamic instability of the reinforcement in the matrix, weak matrix reinforcement interface, inhomogeneous distribution of reinforcement particles, and lack of good elevated temperature mechanical properties. To overcome these problems, researchers came up with in situ processing of composites. (2) 2.2 Aluminium Matrix Composites by In-Situ Process In situ composites are a class of composite materials in which the reinforcement is formed within the matrix by reaction during the processing [7]. Recently, in situ techniques have been developed to fabricate aluminium based metal matrix composites. In the in situ process, ultrafine ceramic particles are formed in situ by the exothermic reaction between the elements or their compounds with molten aluminium alloy. The in-situ routes provide advantages such as uniform distribution of reinforcement, finer reinforcement particle size, clear interface, and thermodynamically stable reinforcement in comparison to the conventional ex-situ processes [2]. These advantages will lead to better and improved mechanical and tribological properties of the in-situ composites when 3 compared with the matrix alloy. By adopting in situ techniques, MMCs with a wide range of matrix materials and second phase particles can be produced [6]. There are several types of in-situ processes, among them, one of the newest methods of synthesizing the in-situ metal matrix composites is through pyrolysis of organic material in metallic melts for reinforcing nano-sized particles. Pyrolysis is the thermal decomposition of organic materials at high temperatures in the absence of oxygen. Products of pyrolysis are mostly ceramic particles made mainly of silicon, oxygen, carbon, and a nitrogen atom. The precursor is itself converted into a ceramic one. The in- situ synthesis of the metal matrix composites through pyrolysis is a potentially inexpensive method because of the availability and low cost of organic materials, the simplicity of the process, and the general characteristics of the in-situ method. The gas released during pyrolysis may have two effects. On the one hand, it may result in gas entrapment and dissolution. On the other hand, it could assist fragmentation and uniform distribution of the particles in the melt .

Advantages of In-Situ Process

Following are a few advantages of the in-situ processes over conventional methods: i. In situ synthesized reinforcement is thermodynamically stable. The reinforcement is formed as an equilibrium product of reactions involving the molten alloy matrix and hence is stable during service. ii. Less degradation in elevated-temperature services. The wettability of the particle with the matrix is good and because of the clean interface, the bonding between the particle and the matrix is better, which will enhance the high-temperature properties. iii. The in situ formed reinforcements are finer in size. Such fine particles are difficult to be added to ex-situ composites as they might choke the feeder. iv. The distribution of reinforcement in the matrix is more uniform due to better wettability and stirring during processing

MATERIALS AND METHODS

Polymer Derived Ceramics (PDC)

Pyrolysis of pre-ceramic polymers is an emerging technology that is used to produce amorphous and crystalline carbide or nitride-based ceramics [1]. These are made from organic precursors which, when heated, typically, from 400°C to 1000°C, decomposed to yield ceramics. Non-oxide ceramic reinforced aluminium matrix composites offer significant performance advantages over pure metals and metallic alloys for advanced structural and technological applications. Silicon carbonitride (SiCN) and composites are remarkable materials for their combination of mechanical and thermal properties at high temperatures [1]. They fall into two classes, those that produce oxide phases such as

ZrO2, TiO2, and SiO2 and those that produce silicon-based ceramics. The latter include SiC and also amorphous ceramics that are constituted from Si-C-N-O. PDCs have drawn much research interest since their emergence for the following advantages: near net shape forming, low process cost, and the ability to achieve homogeneous reinforcing elements distribution at the t molecular level. There are a few groups of PDCs, and the oversimplified general formula is presented in figure 2.1

$$\left[\,\overset{R^1}{\underset{R^2}{Si}}-X\,\right]_n$$

Figure 2.1 General simplified ceramic precursor formula

The variation of (X) results in different classes of Si-based polymers such as polysilanes with X = Si, polycarbosilanes with X = $CCHH2$, polysiloxanes with X = O, and polysiloxanes with X = NH. Typical polymer precursors commonly used include polycarbosilane (PCS), polysiloxane (PSO), and polysilazane (PSZ), producing amorphous Si-C, Si-O-Si, and Si-C-N ceramics respectively upon pyrolysis. The processing of ceramic precursors could be divided into 4 segments: 1) Shaping, 2) Polymer cross-linking, 3) Polymer-to-Ceramic conversion, and 4) Ceramic crystallization. In each segment, the precursor undergoes different chemical reactions, oligomer evaporate and gas release at different temperatures, as shown in Fi Figure 2.2 Different stages during polymer to ceramic conversion [9]
gures 2 and 3 [10].

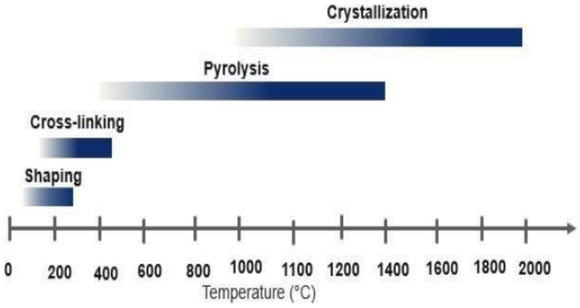


Figure 2.2 Different stages during polymer to ceramic conversion [9]

This process involves the initial cross-linking of polymer precursors followed by a thermal-induced polymer to ceramic transformation by removing the polymer chains and leaving the ceramic backbone. Both the polysiloxanes and polysilazane are large macromolecules, not linear chains. When cross-linked they form three-dimensional networks. A schematic of such a structure constructed from Si, C, O, and H atoms for polysiloxanes is shown in figure 3

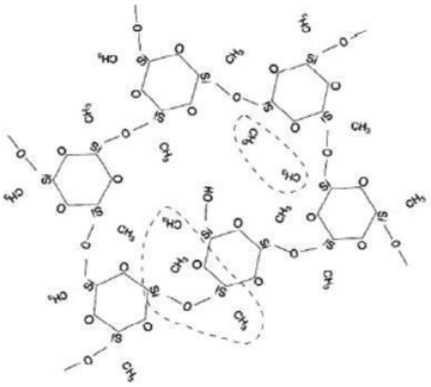


Figure 2.3: Structure of polysiloxanes [10]

The molecular structures of SiCO and SiCN ceramic phases are derived from various organic precursors in an argon atmosphere. During pyrolysis, H–C, Si–H, and N–H bonds are broken within the polymer molecules to form covalent bonds between Si, C, and N atoms through the evolution of methane and hydrogen gas. After the complete conversion of polymer into ceramic phase, the PDC particles exhibit amorphous structures and this amorphous network consists of a mixture of a variety of covalent bonds between Si–C, Si–O, and Si–N, and C–C atoms [12].

2.1 Fabrication of SiOC Ceramic Microparts and Patterned Structures from Polysiloxanes via Liquid Cast and Pyrolysis

SiOC ceramic micro parts and patterned microstructures are fabricated from their metal masters using polysiloxanes as a precursor, which consists of poly-hydro methylsiloxane (PHMS) and 1,3,5,7-tetramethyl-1,3,5,7-tetravinylcyclotetrasiloxane (D4Vi), via mold transfer, liquid cast, crosslink, and pyrolysis. The mixed liquid of PHMS and D4V was cast with the polydimethylsiloxane (PDMS) negative molds transferred from the masters and solidified via hydrosilylation of PHMS and D4Vi under controlled heating. Because both the precursors and mold materials are polysiloxanes, their chemical similarities ensure the excellent contact between the two phases that allow for the precise duplication of the master microstructures into the polysiloxanes. [6] Strategies were developed for the use of a two- step controlled heating method and the use of polysiloxane as a support in the processes of demolding, crosslinking, and pyrolysis to ensure the bonding qualities of both the crosslinked bodies and the pyrolyzed microstructures. Through this route, we obtained dense and crack- free SiOC ceramic micron gears and arrayed holes of well-duplicated microstructures with a resolution down to the submicrometer. Moreover, the polysiloxanes allow the direct imprints with the metal masters to form inversed microstructures of SiOC ceramics, as demonstrated by the formation of microchannels and various motifs of SiOC ceramics from their metal counterparts.[8]

2.2 Stir Casting Processing of MMC

Stir casting is the economical, effortless, and most commercially adopted technique, and it is known as ‘the vortex technique’. In this process, reinforcing phases (ceramic particles, short fibers) introduce by the mean of mechanical stirring into molten metal. PAMMC was stirred by S. Ray first time in 1968, where alumina (Al2O3) particles are introduced into molten aluminum by mechanical stirring. The major disadvantage of this process is an agglomeration of particles during the fabrication process. The mechanism to avoid the agglomeration of particles is achieved through a coating of the reinforcement and inert gas environment during the fabrication process.[10]

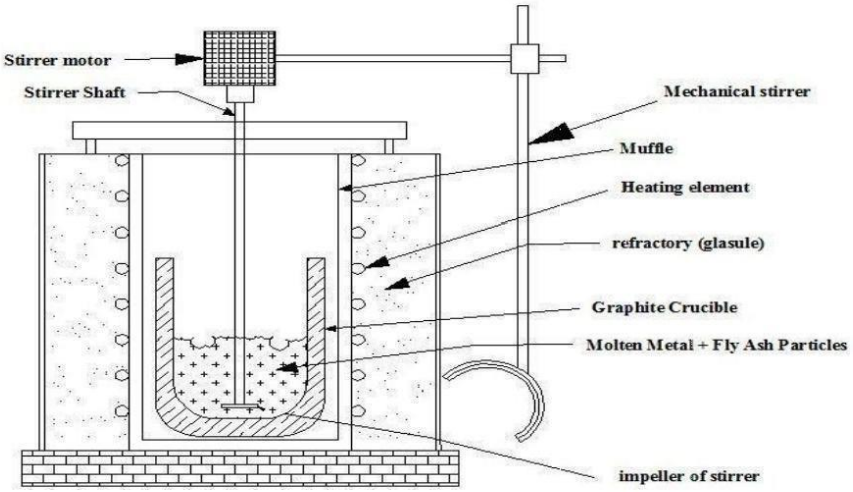


Figure 2.4: Stir casting setup

Reinforcement in the particulate form of up to 30% by weight can be added to the molten alloy, to achieve a better distribution of the reinforcement. [5]Reinforcement is added forcefully into the molten stage of aluminium and obtaining homogeneity during solidification of the fabricated composite depends on the following factors.

- Stirring speed and time
- Stirring blade angle
- Pouring temperature and solidification rate
- Reinforcement’s size, percentage, and relative density

The two-step and electromagnetic stir casting process improves the homogeneity of particles during fabrication. MMCs possess high specific strength, greater strength to weight ratio at elevated temperature, and greater wear resistance as compared to the matrix phase.[11]

2.3 Age Hardening and Precipitation Behaviour by T6 Treatment

The typical thermal treatment for automotive components made by Al foundry alloy is T6 temper, which generally induces higher alloy strengthening. The T6 thermal cycle consists of a solution heat treatment followed by a water quenching and then an age- hardening (or precipitationhardening).

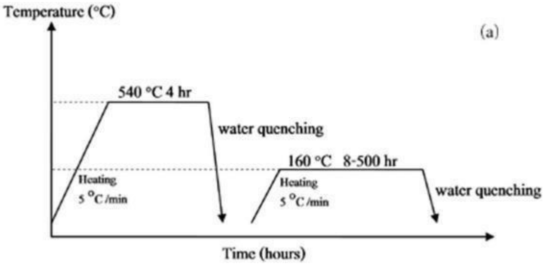


Figure 2.5: Schedule of heat treatment: T6 artificial aging

The solution heat treatment leads to the dissolution of intermetallic phases and the spheroidization of eutectic Si with a resulting improvement of alloy ductility. The time for solution treatment is strongly dependent on the microstructural scale, ranging from a few minutes up to several hours. [4] In general, too short solution treatment does not guarantee that all alloying elements are dissolved in the α-Al matrix and made available for further precipitation hardening; on the contrary, too long solution treatment shows economic limitations because it uses more energy and time than necessary. Age hardening at room temperature (natural aging) or elevated temperature (artificial aging, AA) increases the alloy strengthening because of the ultra-fine particles which precipitate from the supersaturated solid solution and act as obstacles to the dislocation movement[4]. Al-Mg-Si alloys are age hardenable and widely used in both cast and wrought forms. The strengthening of Al-Mg-Si alloys is based on a precipitation-hardening process. Application of the T6 treatment results in a decreasing intensive and yield strength but a significant increase in ductility. A precipitation sequence that is generally accepted is,

SSS α ➡ GP zones (spheres or needles) ➡ $\beta^{//}$ (needles) ➡ $\beta^{/}$ (rods) ➡ β (plates, Mg_2Si or nonstoichiometric Mg_xSi_y)

SSS denotes “supersaturated solid solution” and GP denotes “Guinier-Preston”. Another precipitation sequence with more detail on the earlier stage of clustering and GP-zone formation was proposed [6] as:

SSS α ➡ clusters of Si atoms ➡ GP-I zones ➡ GP-II zones or $\beta^{//}$ ➡ $\beta^{/}$ ➡ β (Mg_2Si).[4]

2.4 Microstructure Analysis A356 After Age Hardening

The optimum balance of strength and ductility attained after thermal treatment is attributed to the changes in eutectic Si characteristics resulting from the solution treatment and to the formation of non-equilibrium precipitates of $\beta^{/}$ resulting from the aging treatment. The maximum solubility of Si in Al is 0.05 wt% at room temperature and the alloy contains 6.5-7.5 wt% Si, accordingly, any excess Si exists as relatively large (1-10 µm) eutectic Si platelets. After T6 treatment, in the as-cast condition**, segregation of Si to the edge of the dendrite** is observed. The eutectic structure contains mainly **Si flakes and Fe-bearing intermetallic compounds** including the p-Chinese script phase ($Al_8Mg_3FeSi_6$) and b(Al_5FeSi) during SEM analysis. [4]

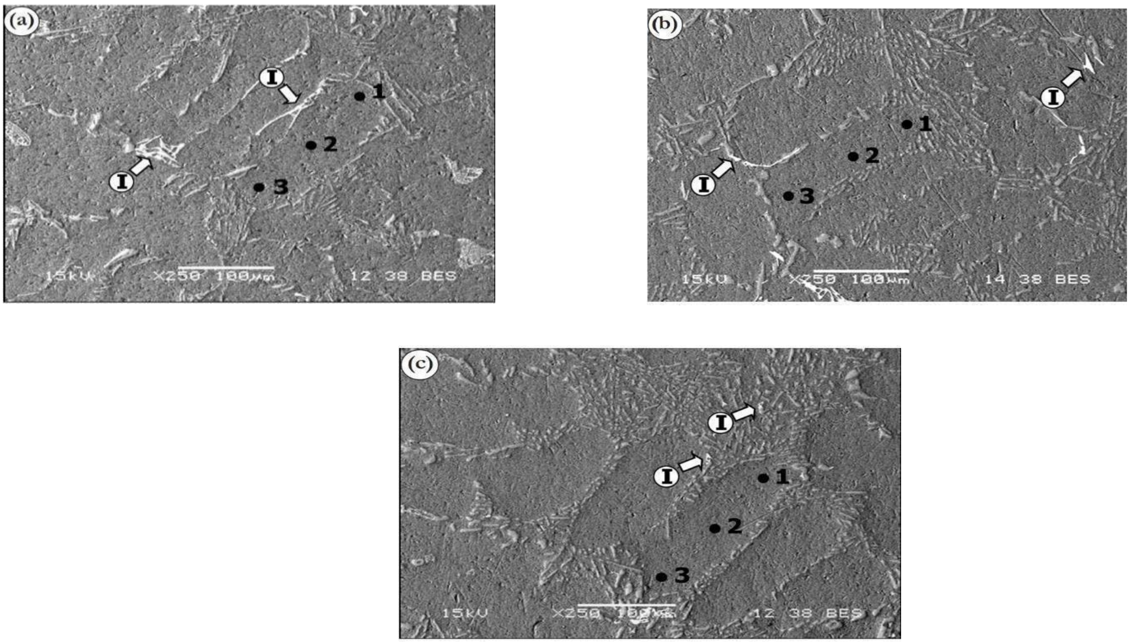


Figure 2.6: SEM-BEI of unetched specimens in (a) as-cast, (b) solutionized, and (c) T6 aged conditions. ‘I’ marked intermetallic compounds associated with the eutectic structure.

SiC Reinforced A356 Composites

SiC reinforced A356 composites produced by mechanical stir casting process and electromagnetic stir casting process. The microstructure of the composites revealed that SiC particles were not distributed evenly and regional clusters of particles existed in the matrix, fabricated by the mechanical stir casting process. But, in the electromagnetic stir casting process, SiC particles were distributed evenly. In the mechanical stir casting process, the nonuniform distribution of the particles is mainly associated with the segregation effects of SiC particles during the solidification of the composite. But, in the electromagnetic stir casting process, the matrix alloy tends to deform in a plastic manner. This indicates that the technique electromagnetic stir casting process utilized for the production of the composite is efficient. Further, the microphotographs of A356/SiC metal matrix composites produced by the electromagnetic stir casting process reveal an excellent bond between the matrix alloy and the reinforcement particles.[3]

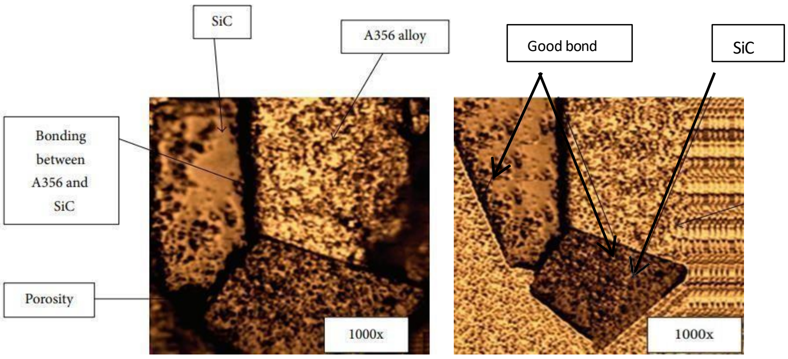


Figure 2.7: Optical micrograph of A356/SiC composite at higher magnification indicating bond between the matrix alloy (A356) and SiC particle; (a) mechanical stir casting sample (b) electromagnetic stir casting sample.

By studying the properties of A356/SiC composites produced by mechanical stirring and electromagnetic stirring, the following conclusions can be drawn.

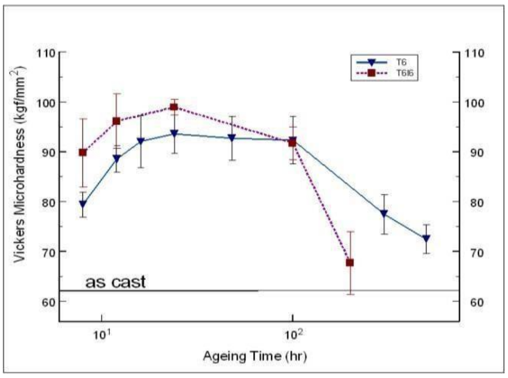
(1) Compared with the macrostructure and microstructures obtained by mechanical stirring, the macro-and microstructures obtained by electromagnetic stirring were homogenous.

(2) Measured data with big deviation were observed in mechanical stir casting samples but, in electromagnetic stir casting samples, the deviation of measured data was not so high. This is because of porosity observed in mechanical stir casting samples. ([3]

2.5 Hardness Properties After Fabrication and Heat Treatment

Aging hardening by T6 and T6I6 increases the Vickers microhardness from the as- cast value by 52% and 60%, respectively. The peak hardness by T6I6 is approximately 8% higher than that obtained by T6. The rate of decrease in hardness from the peak hardness in the over- aging period is faster in the case of T6I6.

Figure2. 8: Relationship between Vickers microhardness and the aging time of the alloy after T6 or T6I6 heat treatme



Application of Aluminium Hybrid Composites in the Automotive Industry

where they enhance the performance of various components. In engine pistons and cylinders, MMCs provide better wear resistance and thermal conductivity, reducing weight and increasing longevity. Aluminium MMCs also reduce the mass of engine connection rods by 57%, lowering vibrations and improving fuel efficiency. Additionally, these composites are used in brake systems for their high wear resistance, thermal conductivity, and ability to reduce inertial forces, contributing to overall weight reduction and improved performance.

OBJECTIVES AND SCOPE OF PROJECT

3.1 Objectives

- To fabricate A356 based in-situ metal matrix composite with 2.5 volume % of SiOC ceramic particles.
- To study and compare the age-hardening behaviour of composites with A356 base material.

3.2 Scope of Project

- To study the age-hardening behaviour of A356 based on in situ metal matrix composites.
- To understand the effects of temperature and time on age-hardening behaviour.

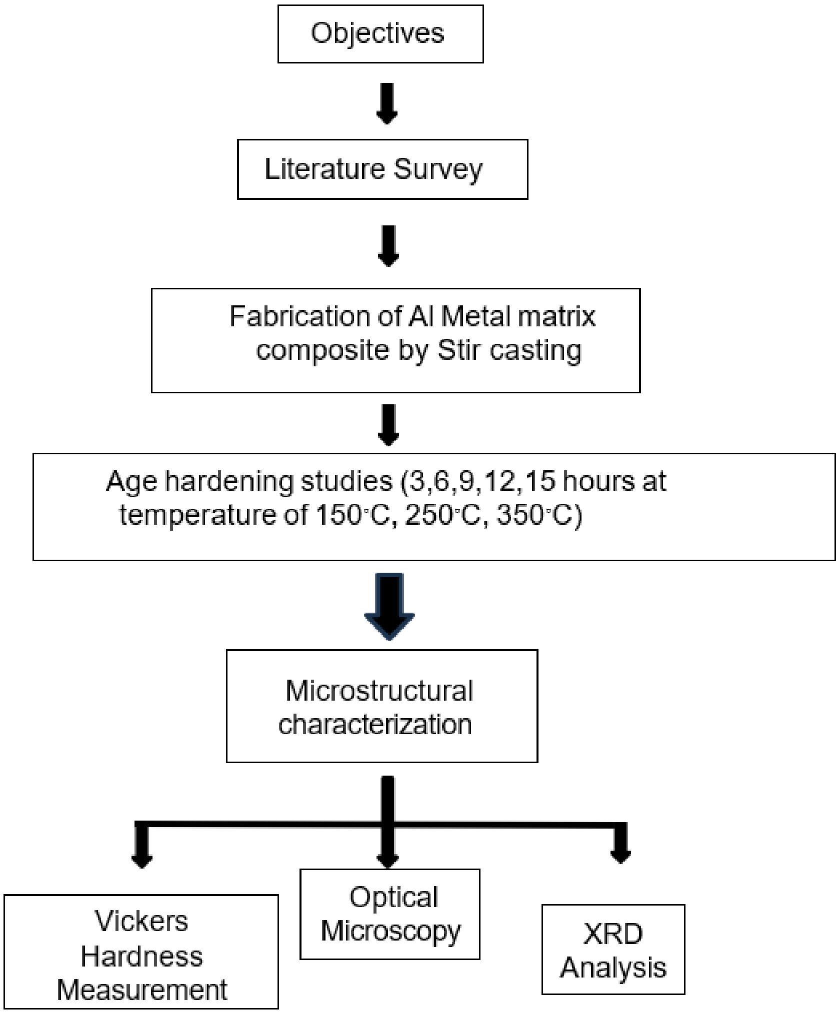


Fig 4.1 Methodology of the project

EXPERIMENTAL WORKS

The chemical composition of A356 alloy was shown in the Table 5.1

Table 5.1: The chemical composition of experimental cast Al-Mg-Si alloy equivalent to A356 (in wt.%)

Elements	Si	Mg	Fe	Mn	Ti	Ni	Al
wt. %	7.32	0.03	0.147	0.006	0.127	0.005	Bal.

5.1 A356 Base Metal Preparation

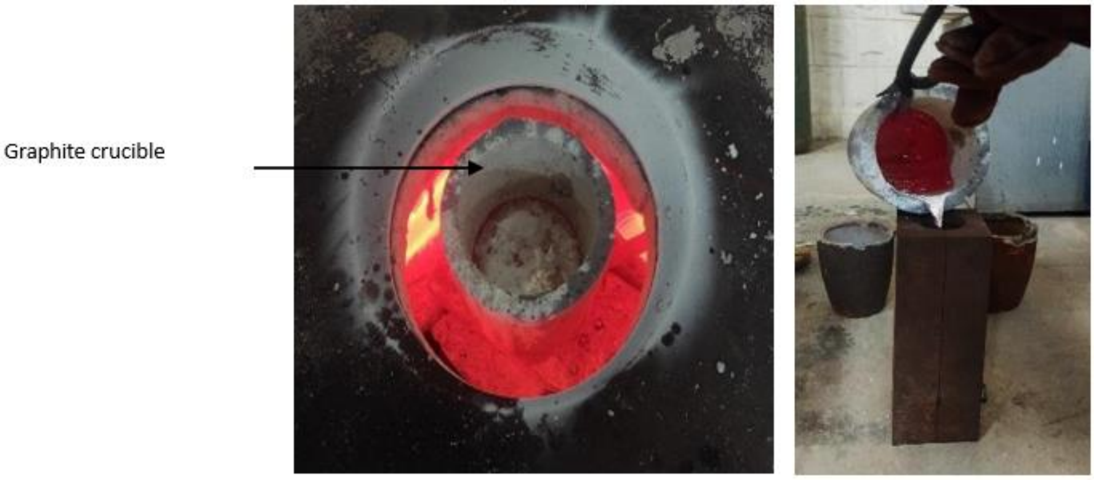


Fig 5.1: A356 Base -Mould preparation

In this study, A356 alloy is selected as the base metal. Melting of 1kg of A356 alloy is carried out in a Vertical muffle furnace loaded in a graphite crucible at 700 ⁰C and transferred to a cylindrical mold made of mild steel with a dimension of 240mm x 40mm.

5.1 Fabrication of Al Metal Matrix Composite by Stir Casting

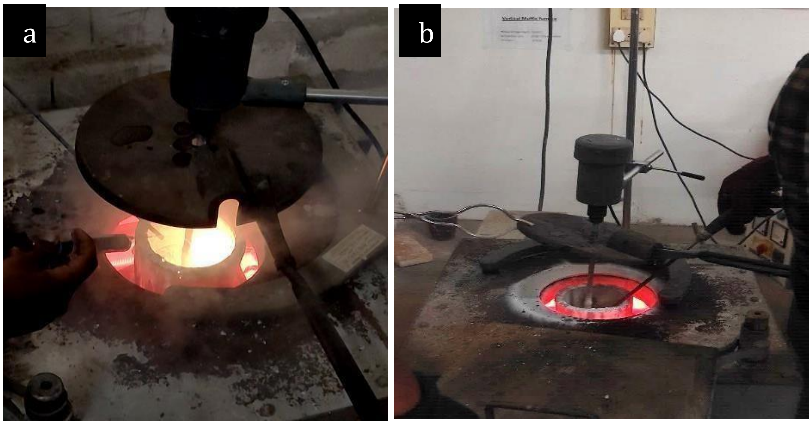


Fig 5.2 (a) and (b) stir casting of A356 + 2.5% SiOC Fig 5.3Test specimens

Stir casting of one kg of A356 alloy was carried out in a Vertical Muffle furnace and heated upto 700⁰ C under an argon atmosphere. Then 2.79 % of Polymer precursor Polysiloxane was gradually added to the vortex in the form of liquid. The amount of polymer added to the melt was adjusted to achieve an estimated volume fraction of 2.5% of SiOC ceramic particles. Stirring continued for 15 minutes with a speed of 700 rpm using a controllable graphite stirrer and liquid Polysiloxane was added frequently. Each addition was proceeded by some gas release from the melt. Degassing is carried out where Argon gas is purged for

3 minutes to remove Hydrogen gas which causes porosity in the material. K Type thermocouple is used to indicate temperature. The slurry was then poured into a mild steel cylindrical mold of dimension 240mm x 40mm and solidified. The calculation for the weight fraction of polymer precursor to being injected in the melt is calculated based on the below formula

$$w_f^{precursor} = \frac{\rho_{PDC}}{Y * \rho_{matrix}} v_F^{PDC} \text{ -----(1)}$$

And the weight fraction of precursor was calculated to be 2.79% with the Yield of ceramics = 0.75, Density of PDC ρ_{PDC} = 2.2 g/cc, Density of matrix ρ_{matrix} = 2.71 g/cc, Volume fraction of PDC v_f^{PDC} = 0.025

5.5 Age Hardening Studies

Fig 5.4. a) A356 Base metal b) Al metal matrix composite

After the stir casting process, samples were cut into 30 pieces with the the dimension of 10mm x 10mm x 4mm. The test samples were solution heat-treated at a temperature of 540° C in a vertical muffle furnace, soaked for 6 hours, and then rapidly quenched in water. Thereafter, T6 artificial aging was done at temperatures of 150° C, 250° C, and 350° C for various aging times until the peak aging was exceeded for both the base metal and the Al MMC. The aging characteristics were evaluated using hardness values obtained from the solution heat-treated and thermally aged samples. The Age hardening details of base metal & Al MMC are mentioned in table 5.2

Table 5.2: Age hardening details of base metal & Al MMC

SAMPLES	**TEMPERATURE**	**TIME**
BASE -5 Samples Al MMC- 5 Samples	150° C	3,6,9,12,15 hours
BASE -5 samples Al MMC- 5 Samples	250° C	3,6,9,12,15 hours
BASE -5 samples Al MMC- 5 Samples	350° C	3,6,9,12,15 hours

5.5 Microstructural characterization

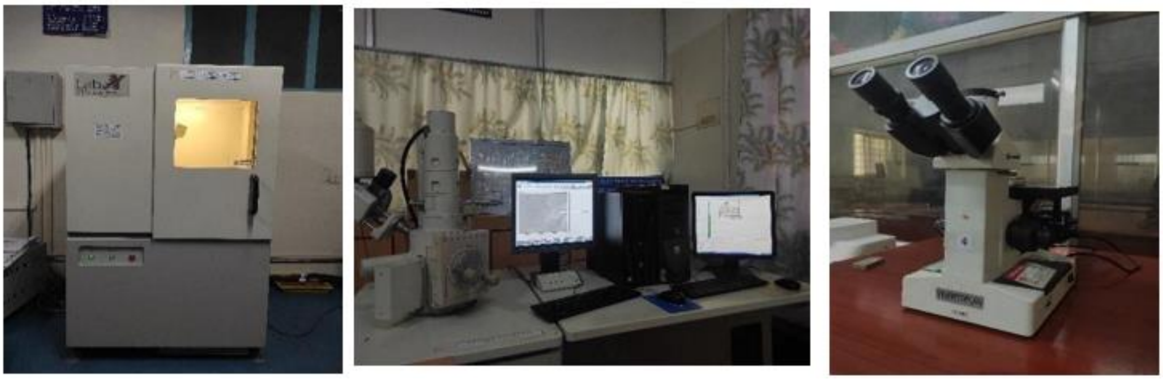


Fig 5.5 a) XRD b) SEM c) Optical microscope

The base metal and Al composites were cut into small specimens of 10mm x 10mm x 4mm and then ground to flat surfaces. These specimens were polished by emery grades of decreasing grain size (150,350,1000,1200,1500,2000) to achieve a scratch-free surface and finally, these specimens were disc polished with alumina to achieve a mirror-like surface. The polished samples were etched with 10%HF and then examined under an Optical microscope, SEM, and XRD to analyse the presence of phases, distribution of grains, and reinforcement particles.

Hardness Analysis

Fig 5.6 Vickers hardness test machine

Hardness values were measured using Mitutoyo Micro- hardness tester on a Vickers scale with a load of 500g for 15 seconds. The base metal and the Al MMC samples were polished and then subjected to a diamond Pyramid indenter of 136⁰ indenter angle between the opposite faces of the pyramid. Five readings were taken for each sample in different locations and the average hardness value for each sample was reported.

RESULTS AND DISCUSSION

Optical Microstructural characterization

Optical Microstructure of Base Metal A356 before T6 Treatment

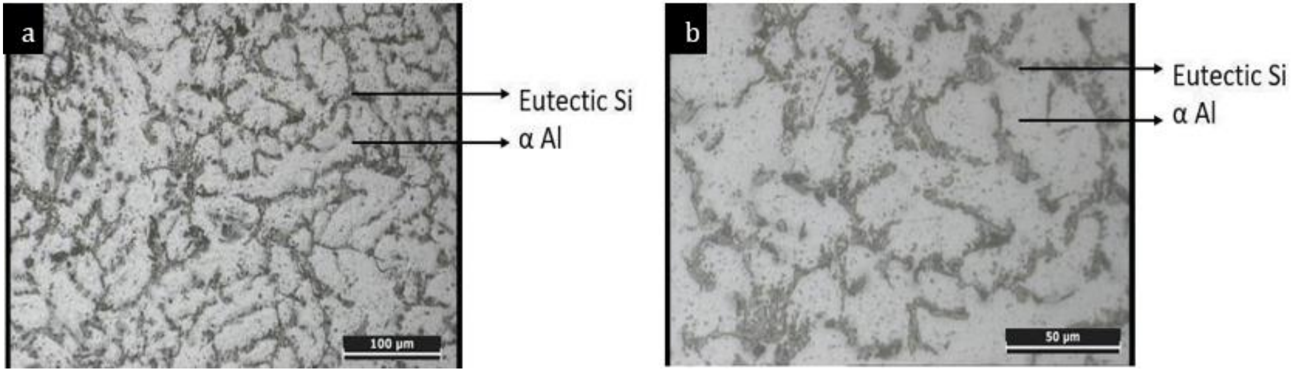


Fig 6.1. Microstructure of A356 Base revealed using HF reagent (a) 200x (b) 400x

The microstructure of A356 base metal is shown in Fig 6.1 (a) 200x (b) 400x. The Microstructure revealed the presence of eutectic Si as thin plates in the alpha Al matrix.

Optical Microstructure of Al MMC before T6 treatment

The microstructure of A356+2.5 wt.% SiOC is shown in Fig.6.2 a)100x (b)400x. The microstructure revealed the presence of eutectic Si and the uniform distribution of SiOC reinforcement phase in the α-Al matrix. The uniform distribution of the ceramic particle in the matrix is attributed to the adequate stirring of the composite mixture during melting. From the investigation that adequate stirring of the molten metal had produced a vortex in the mixture

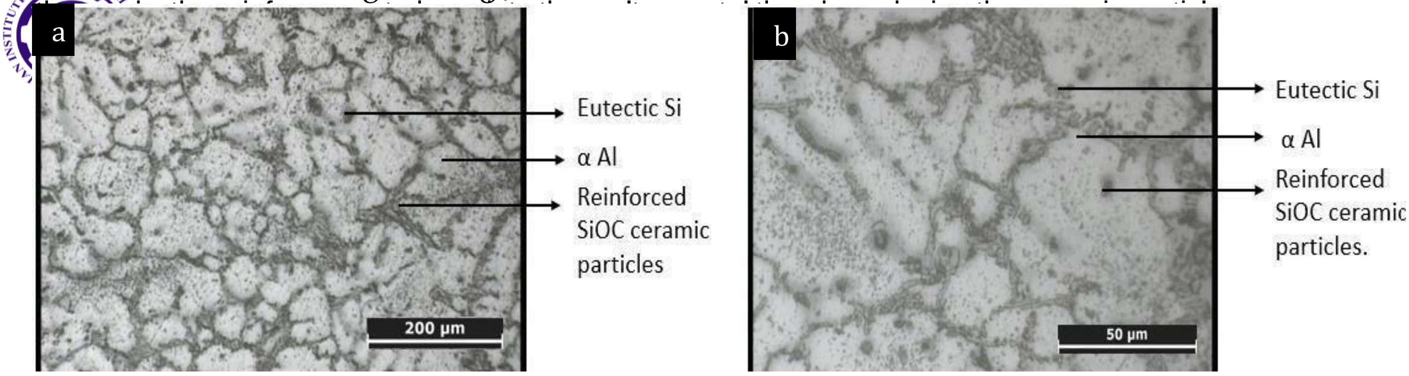


Fig 6.2: Microstructure of A356+2.5 wt. % of SiOC revealed using HF reagent (a)100x (b)400x

Optical Microstructure of Base metal revealed after age-hardening by T6 Treatment at 150° C

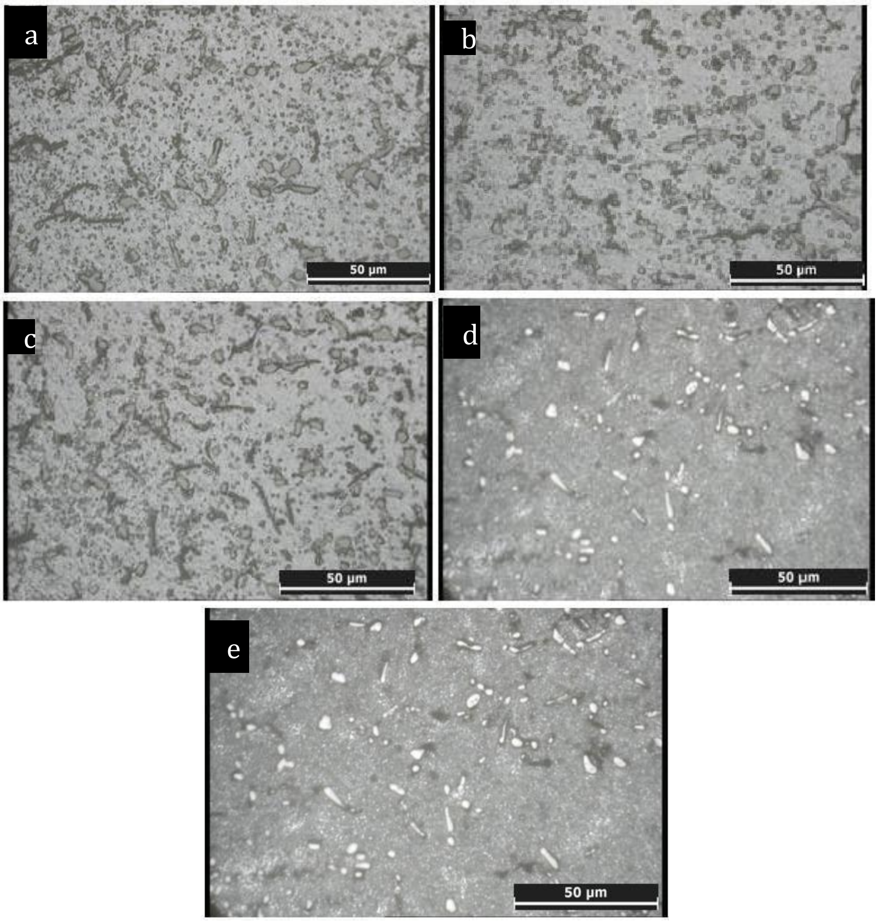


Fig 6.3: Optical Microstructure of Base metal revealed after age-hardened at 150° C a) 3hours b) 6 hours c) 9 hours d) 12 hours e) 15 hours

igures 6.3 show microstructures for base metal after age-hardening at 150 ° C for 3,6,9,12,15 hours. The microstructure of the base metal reveals the presence of both fine and coarse Si particles with globular morphology. Due to the mechanical stirring of the A356 alloy in a semi- solid state, the Si needles are converted to globular shape at all aging time intervals. Mg2Si precipitates were observed in 12 and 15 hours of aging time

Optical Microstructure of Al MMC revealed after age-hardening by T6 Treatment at 350^0 C

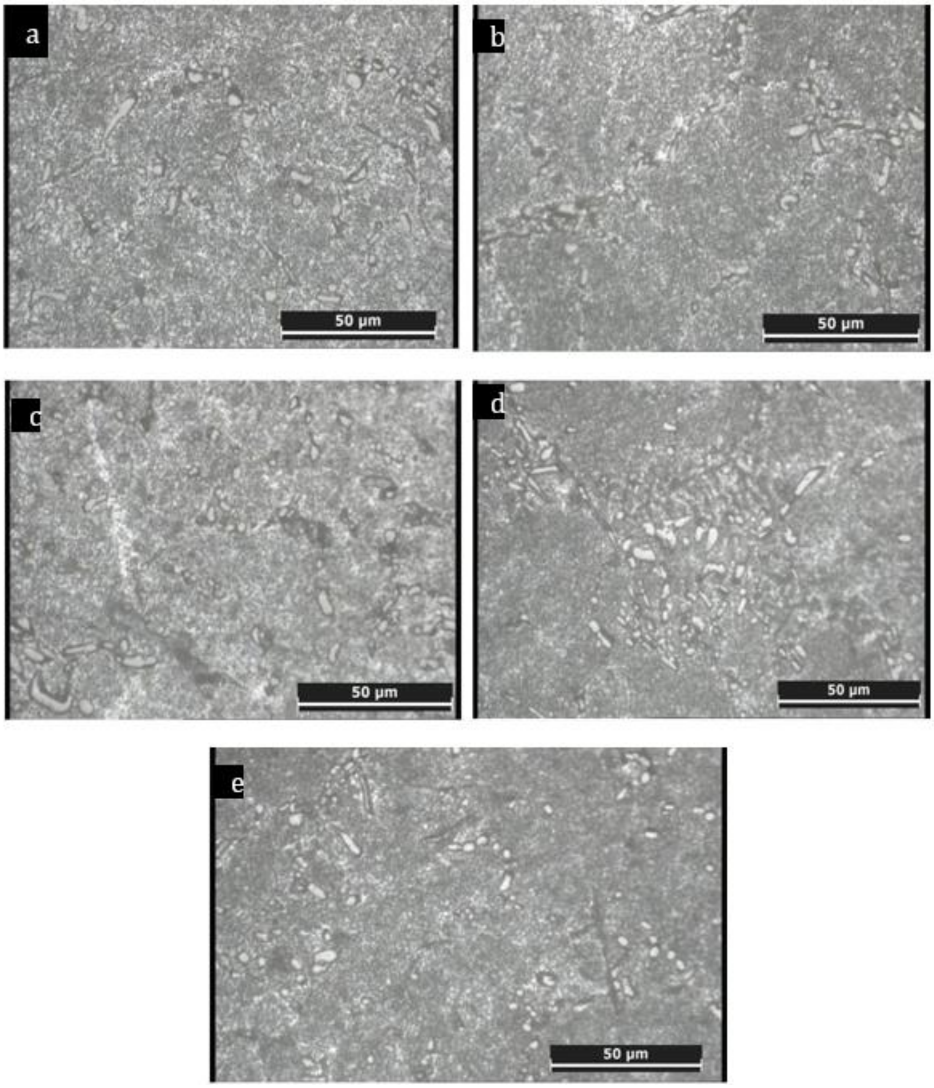


Fig 6.8: Optical Microstructure of Al MMC revealed after age-hardened at 350^0 C a) 3hours b) 6 hours c) 9 hours d) 12 hours e) 15 hours

Scanning Electron Microscope (SEM) Characterization

SEM Microstructure of Base Metal A356 after T6 Treatment

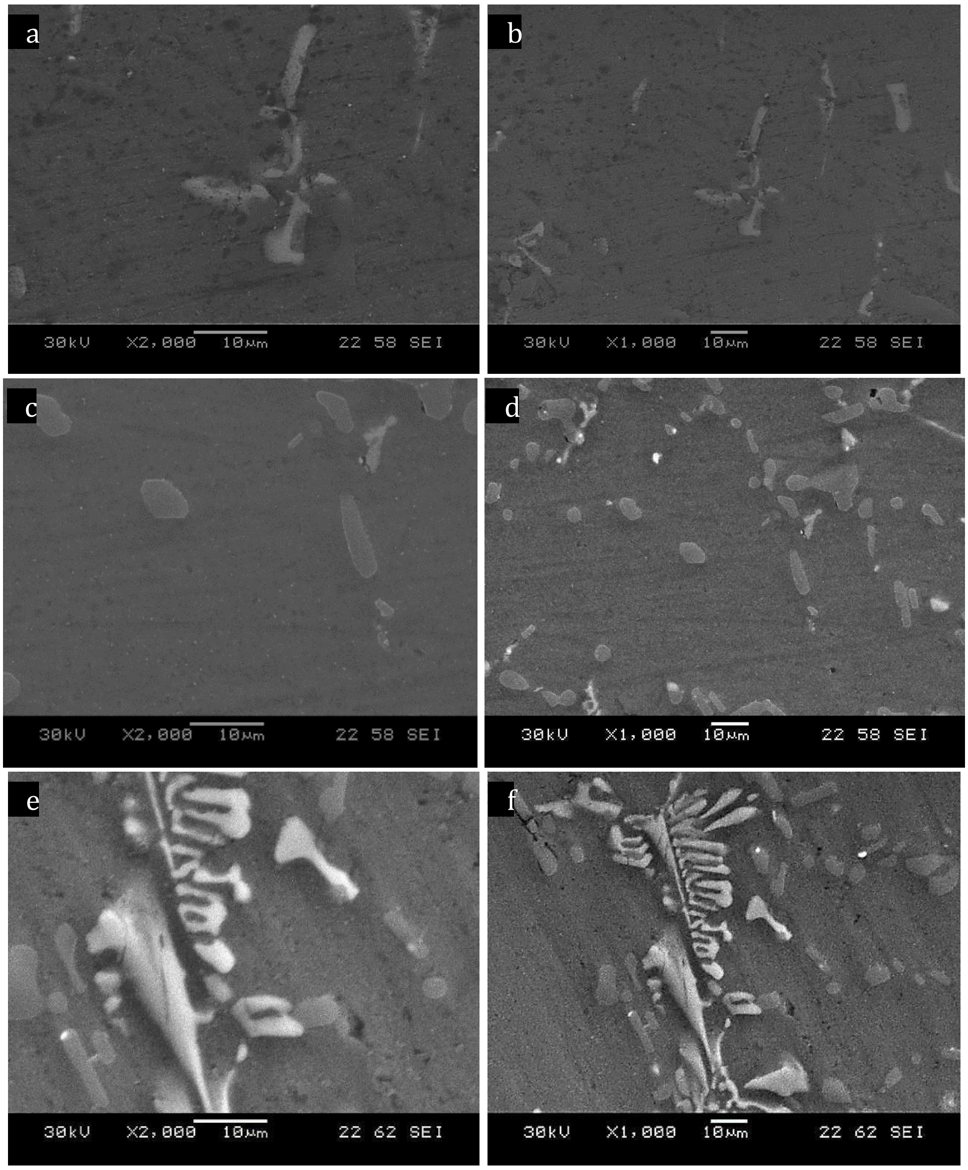


Fig 6.9: SEM images of base metal revealed after age-hardened at 150^0 C a) 3hours-2000x b) 3 hours-1000x c) 9 hours-2000x d) 9 hours-1000x e) 15 hours-2000x f)15 hours-1000x

Figure 6.9 shows the SEM images of the base metal aged at 150^0 C.. At 3 hours, Mg2 Si were observed (white region). At 9 hours, globular Si particles are observed. At 15 hours, as the aging time increases, dendritic morphology of Mg2 Si is observed which leads to a decrease in hardness.

SEM Microstructure of Al MMC after T6 Treatment

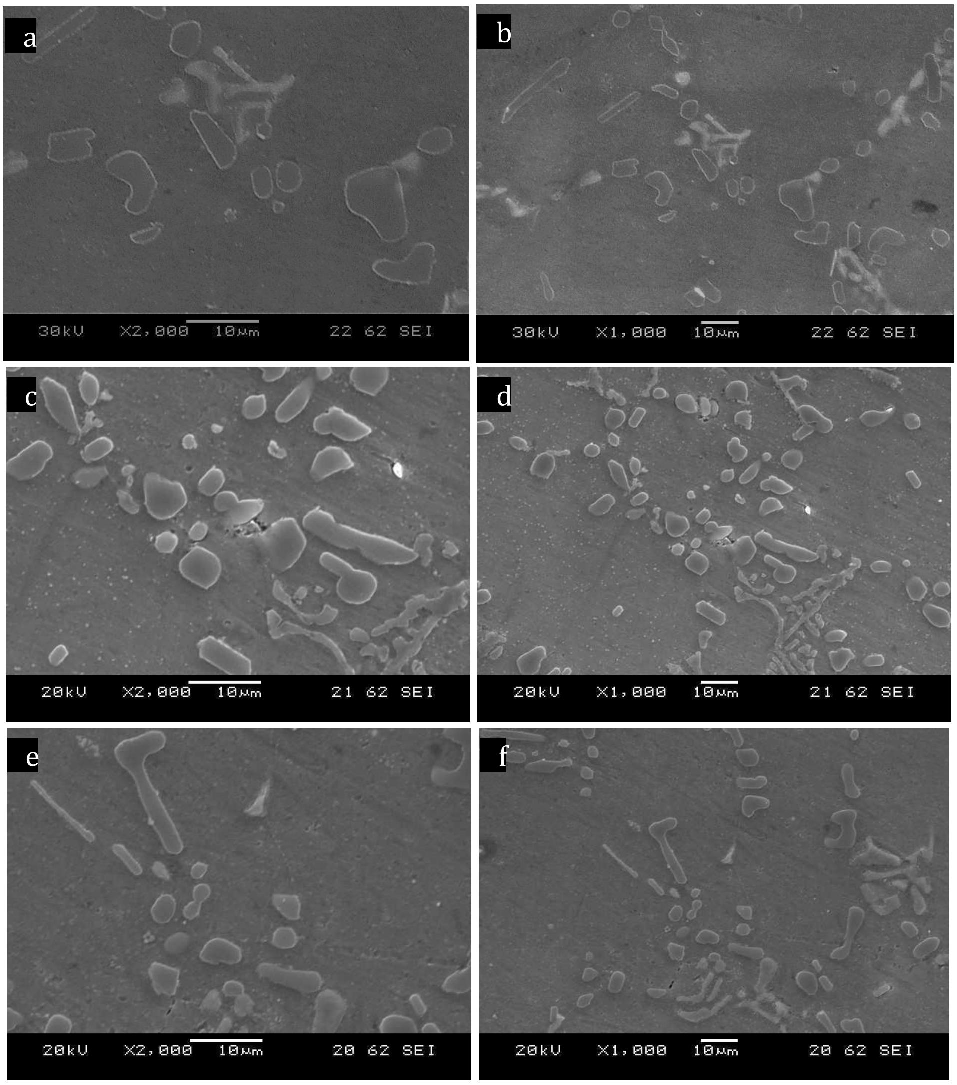
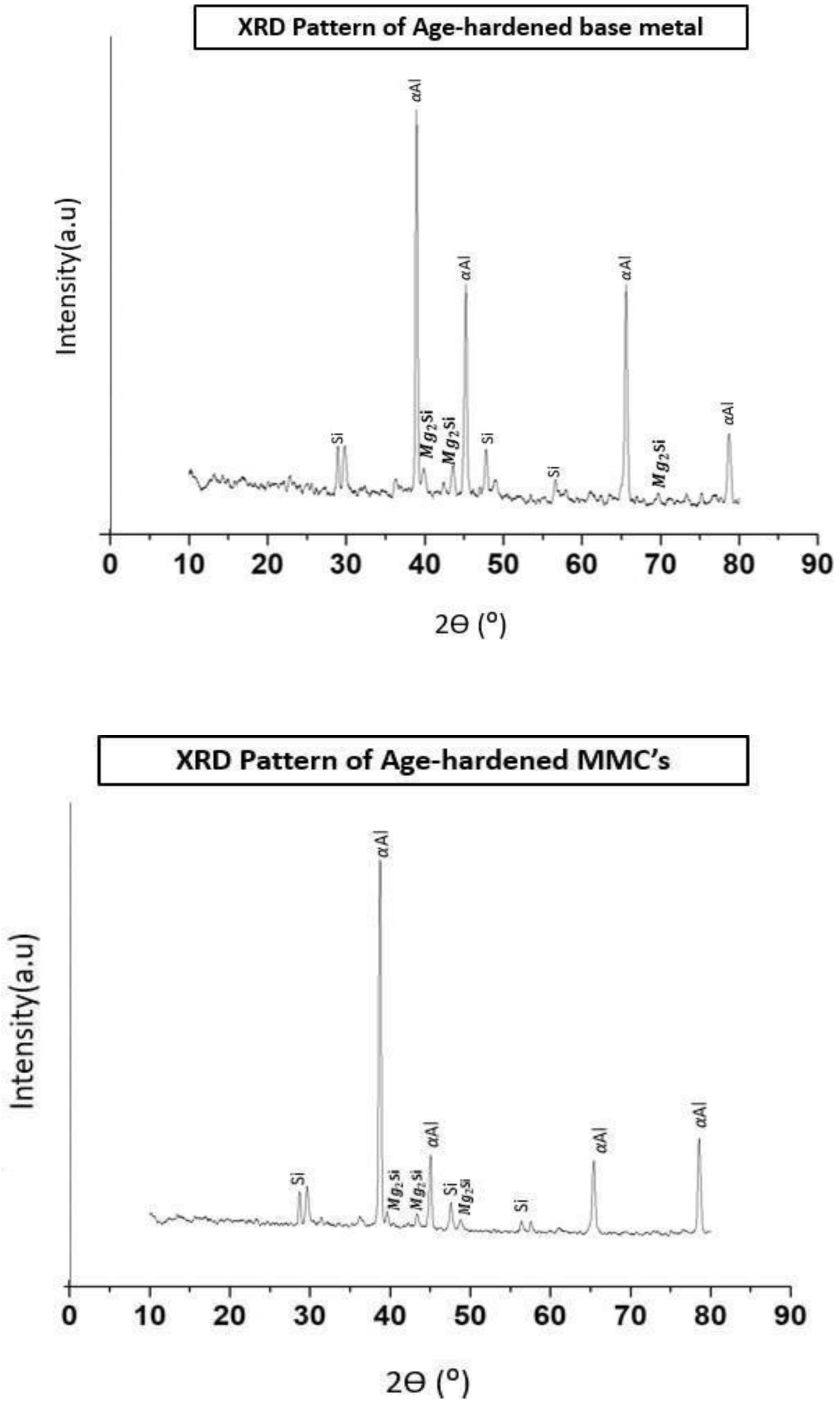


Fig 6.10: SEM images of Al MMC revealed after age-hardened at 150º C a) 3hours-2000x
c) 3 hours-1000x c) 9 hours-2000x d) 9 hours-1000x e) 15 hours-2000x f)15 hours-1000x

Figure 6.10 shows the SEM images of Al MMC aged at 150º C. Globular Si, and precipitates such as Mg2 Si (white regions) were observed at 3 hours of aging time. Reinforced SiOC ceramic particles were observed at 9 and 15 hours of aging time

Ray Diffraction Characterization

XRD of Base Metal and Al MMC’s after T6 Treatment



(a)

(b)

Fig 6.11 XRD of (a) Base Metal (12 hours) (b) Al MMC’s(9 hours) of 2.5% reinforcement

CONCLUSIONS

An investigation was conducted on the age-hardening behaviour of A356+2.5% SiOC composite and the base metal and the following observations were noted.

- Microstructural Characterization revealed uniform distribution of ceramic particles due to in-situ pyrolysis and grain refinement due to the presence of ceramic particles that act as heterogeneous nucleation sites.

- From XRD analysis, eutectic Si, α-Al and undissolved precipitates of Mg and Si forms an intermediate phase of Mg2Si was observed.
- From age-hardening studies, it was noted that the value of hardness was found to increase from the base alloy to the heat-treated composite alloy for all three different age-hardening temperatures.
- Also, it was observed that the presence of SiOC particles in the matrix decreases the time required to attain the peak hardness in the composite.

BIBLIOGRAPHY

1. Chidozie Chukwuemeka Nwobi-Okoye a, Basil Quent Ochieze, Age hardening process modeling and optimization of aluminum alloy Cow horn particulate composite,2018
2. Nagaraj M Chelliah1, Padaikathan Pambannan2 and MK Surappa, Solidification characteristics and mechanical properties of in situ magnesium metal matrix composites, 2019
3. Shashi Prakash Dwivedi,1,2 Satpal Sharma,2 and Raghvendra Kumar Mishra, Microstructure and Mechanical Properties of A356 or SiC Metal Matrix Composites Produced by Two Different methods, 14 June 2014
4. Suttawan Imurai, Julatep Kajornchaiyakul, Chachana Thanachayanont, John T.H. Pearce and Torranin Chairuangsri, Age Hardening and Precipitation Behaviour of an Experimental Cast Al-Mg-Si Alloy Treated by T6 and T6I6 Heat Treatments, 26 February 2010
5. Mohammad Senemar1, Behzad Niroumand1, Ali Maleki2, and Pradeep K Rohatgi3, Synthesis of the in situ aluminum matrix composite through pyrolysis of high- temperature vulcanization silicone, 2017
6. Chelliah NM1,2, Sudharsan1, Lisa Kraemer3, Harpreet Singh2, Surappa MK4 and Rishi Raj, A Polymer Route to the Design of Thermally Stable Metal Matrix Composites: Materials Selection and In-situ Processing, 2017
7. B. Stojanović, L. Ivanovic, Application Of Aluminium Hybrid Composites In Automotive Industry,
2015
8. Nagaraj M Chelliah1, Padaikathan Pambannan2, and MK Surappa2,3, Effects of processing conditions on solidification characteristics and mechanical properties of in situ magnesium metal matrix composites derived from polysilazane precursor, 2019
9. Xiang Liu, Ya-Li Li,w and Feng Hou, Fabrication of SiOC Ceramic Microparts and Patterned Structures from Polysiloxanes via Liquid Cast and Pyrolysis, 2009
10. Tianheng Xu, Qingsong Ma ⁎, Zhaohui Chen, The effect of aluminum additive on structure evolution of silicon oxycarbide derived from Polysiloxane,2010
11. Jointoiet Joseph, Bharath S. Pillai, J. Jayanandan, J. Jayagopan, S. Nevada, U.S. Surya Balaji, Karthik
V. Shankar, Mechanical behavior of age-hardened A356TiC MMC
12. Massoud Malaki 1, Alireza Fadaei Tehrani 1, Behzad Niroumand 2 and Amir Abdullah, Ultrasonically Stir Cast SiO2/A356 Metal Matrix Nanocomposites, 12 December 2021