STUDY OF MECHANICAL PROPERTIES AND WEAR BEHAVIOR OF ALUMINUM MATRIX COMPOSITES REINFORCED WITH SILICON CARBIDE PARTICLES

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ABSTRACT
The aim of this research is to study the mechanical properties and wear behavior of aluminum composite material (AMCs) reinforced with silicon carbide particles with varying percentages (0, 3, 6 and 9) wt. %. These composites samples were prepared by stir casting process. Tensile strength, compression strength, hardness and wear resistance of the prepared composites were analyzed. The result showed that adding SiC reinforced in Al matrix increased tensile strength, compression strength, wear resistance and hardness with increased wt. percentage of silicon carbide reinforced AMCs. Maximum tensile and compression strength and hardness showed at 9 wt. percentage SiC reinforced AMCs.
Key words: composite material, stir casting, silicon carbide, mechanical properties

INTRDUCTION

Many engineering application required perfect properties such as high strength, better wear resistance, higher stiffness, low thermal expansion and high thermal conductivity, which may not found in engineering material like alloys and polymers. Therefore need arose for composites material which are a mixture of materials at different phases and mixed to form a composite with require properties of the compound,provided that any of the compounds not dissolve or interact with each other Raminder, Kudlipsingh,[2017].The materials with metals as the base with other metal, ceramic or organic added as reinforcement to enhance the properties are called metal matrix composites (MMCs). The reinforcement will be in the form of continuous or discontinuous fiber, particulates and whiskers. Metal matrix composites have superior properties as compared with the monolithic. Properties of the metallic matrix material composites depend on the properties of the constituent relative amount, their phases, dispersed phase geometry including particle shape، Metal matrix composites with aluminum as base metal are widely used in automobiles, aircraft, aerospace and other field. Non-metallic and ceramic particles such as boron carbide (B4C), alumina (AL2O3), silicon carbide (SiC), graphite, hybrid and fly ash are used as reinforcement in AMCS G.G.Hosamani,Vishal B.,[2016]. AMCs can be fabricated by liquid state processing (squeeze casting, infiltration, stir casting, etc.), powder metallurgy and semisolid processing. The load when applied externally to the composites, metal matrix transmits loads to the reinforcement, and the load carried by dispersed reinforcement. To obtain high strength of composites, strong interface bond between reinforcement and matrix is required. Therefore, good wetting of the reinforcement is required during casting requisite. The purpose of this research is to study the effect of SiC reinforcements in AMCs on the mechanical properties: tensile strength, hardness and Wear resistance.

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EXPERIMENTAL PART

Materials

Aluminum was selected as the base of matrix material and Silicon carbide particles (partical size is 25µm) were added as reinforcements to prepare composites in this study. The chemical composition of Al used as matrix material is given in table 1. To increase the wettability of SiC particales in the molten Al, 1% of (Mg) in ribbon shaped were added to molten aluminum during casting.

Preparation the composite

Mechanical stir casting, which is one of the liquid fabrication techniques, a best economical process for producing composite material and most suitable for Al-SiC combination was used to prepare Al-SiC composite samples(B.Vijaya Ramanth, C. Elanchezhian, [2014]). During this process SiC particle distribute homogenously by forming vortex in molten metallic. Vortex technique provides high strength and homogenous combination. Aluminum (equipping by the universal company for electrical company) cut into small pieces to get the desired weight according to reinforcement SiC particles. Then the sample weighted put in graphite crucible inside the electric furnace and when the temperature of the liquid Al installed at 750ºC, Mg was added to increase a wet ability. Melt was stirred for 10 minutes using electrical mixer at speed 630 rpm to create the vortex. SiC particles preheated to a temperature 300ºc to remove the oxide layer around it's and to make a good link between matrix and particles. Immediately after the creation of vortex in the melt, the reinforced particles added into the melt. The purpose of these vortexes is to pull the silicon carbide particles inside the molten and distributed them homogenously. Then the mixture was poured into preheated suitable metal mold. This process was repeated several times with varying SiC content in weight percentage and the composition as shown in table(2).

MICROSTRUCTURE AND MECHANICAL TESTS

Microstructure

the speciments preparation process were conducted to display the distribution of SiC particles in Al matrix, the specimen were polished on emery papers of different grades(100,120,220,320,500) and polished with alumina powder fluid at softeness(1µm) ,the speciments washed with water and alcoholafter each stage of smoothing and polishing. Microstructure were seen using optical microscope at 500X magnification

Mechanical Tests.

Hardness

Vickers hardness of the samples was determined using (ASTM C1327) in order to examine the influence of SiC particles on matrix hardness at a load of 5 Kg for 10 second.

Wear resistance was measured using pin – on – disc method at room temperature and dry sliding condition using (ASTM D2625-83). The device consists of a rotary steel disc and cylindrical sample to obtain contact between the surface of the sample and the rotary steel disk under the impact of vertical load. The device is also consist of a motor with a constant speed of rotation (940 rpm) and arm with a rectangular section in which the catcher confirms the sample. The wear test was performed using a carbon steel disc with hardness (48 HRC) and rotation speed of disc (510 rpm). Do wear test after installing sliding distance (7cm) and sliding speed (2.7 m/sec). Four different loads were used (5, 10, 15, 20) N for the exposure period 20 min. The amount of weight loss was measured using a sensitive electronic balance type (Denver) with accurate (0.0001 gm.) the wear rate was calculated according to the following equation:

Wear rate (W.R)=$\Delta W/2\pi tRN$

t -time of sliding=20 min

N- Number of disc rotation =510 rpm
R =7 cm
ΔW- difference in weight after and before the test (gm.)
W.R-wear resistance gm./cm

Tensile test was conducted at room temperature using Universal Testing Machine with capacity of (2.5 ton) and speed of (1mm/min). The test specimens were performed using lathe machine according to the specification (ASTM-E8-95). Figure(1). shows the tensile test standard as per ASTM standara, with (12.5 mm) diameter and (62.5mm) in gage length. **Compression test** was conducted using Universal Testing Machine with capacity of (2.5 ton) and speed of (1mm/min). The test were performed according to the specification (ASTM-E8-95). Sampling dimensions (13 mm) diameter and (25 mm) in gage length

RESULT AND DISCUSSION

Microstrcture

Figure(2), Figure(3)and Figure(4) show the optical microstructure of 3, 6 and 9 wt.% SiC reinforced AMCs respectively. The microstructure analysis of these specimen shows clustering and non-homogeneous distribution of SiC particles in Al matrix. That was due to variation of contact time between SiC particles in the moleten Al through composites processing, high surface tension and poor wetting behavior of particles in the molten Al. non-homogeneous distribution of SiC particles in Al matrix observed in microstructure of 9% SiC reinforced. Proposities presence in all microstructureand. That was because SiC particles when added in the melt during composites processing, it introduced air in the melt entrapped between the particles. So increasing wt.% of SiC particles increased entrapped air led to higher amount of porosity. This microistructure analysis is in agood agreement as comparision with (Md.Habibur Rahman, H.M.Mamum ALRashed,[2014] & Pradyumna Phutane, Vijay kumars, [2013]) microstructure analysis.

Hardness

Figure(5) shows vicker hardness value of AMCs varying wt. % of SiC reinforcement. The figure showes enhance in hardness of AMCs with addition of SiC particles when compared with un reinforcement Al. As increasing SiC particles content the hardness value increase and maximum value of hardness obtained for 9 % wt. SiC reinforcement AMCS. The reason for the increasing in the value of hardness is due to the presence of harder and well bonded SiC particles in Al matrix that impede the movement of dislocation. That agreed well with the results of (Manoj single, D.Deepak dwivedi ,[2009] & Muna K. Abbas, Khairia,S.Hassan, and Abbas S.Alwan, [2015]).

Wear resistance

Wear is loss of material from surface (Madeva Nagaral, Bharah, V.[,2013]). Fig.6 shows relation between wear rate and applied load on the AL and AMCS of varying wt. % SiC reinforcement. It is observed that the wear of Al increases with increasing applied load. This because an increase in load increases the elastic deformation at the top of the protrusions and the area near the surface. Thus, the density of the dislocations increase with increasing deformation leading to the formation of precise cracks in the surface of the metal. Then, the intersection of these cracks with each other and with the lines of wear parallel to the separation causing the delamination of parts of the metal at the fine surface layers of the metal and these pieces are easily removed towards the slip and the formation of debris wear. Which leads to increase wear rate [Md.Habibur Rahman, H.M.Mamum ALRashed, 2014, Muna K. Abbas, Khairia, 2009]. It is noted that the wear behavior of Aluminum is similar to the composite material in term of wear of mild wear in the few load of 5N to the transitional wear and then to the severe wear, when the load increasing significantly to 20 N. However, the wear rate of composite material was lower than in the cause of pure Aluminum and in all loads of (5-20) N at constant sliding speed and sliding time. This is due to the role of (SiC) reinforcement particles in increasing the hardness and strengthen the ground of composite material and the occurrence of interactions between the solid (SiC) particles and movements dislocations formed by elastic formation of the surface layers. In additions (SiC) particles have higher hardness than the ground, which helps to resist the over load and also reduces the contact points between the two surfaces at the points of protrusions in the surface layer, so that the force required to cut these protrusions is less than in the cause of pure Aluminum . Thus, the wear rate decreases with increase wt.% of the (SiC) reinforcement particles in the composite material.That agreed well with the results of (A.Venel,A Rac,I.Bobc,[2004] & Muna K. Abbas, Khairia, [2017]) .

Tensile and compression strength

Tensile strength

Figure(7) shows tensile strength of AMCs with varying wt.% of SiC reinforcement. It is observed the increasing of tensile strength with increasing wt.% SiC content in aluminum matrix because of applied tensile load will be transfer to the strongly bonded SiC reinforcement in AMCs which improves the tensile strength. This analysis is in agood agreement as comparision with (K Karvani , D Fasnakis , [2016]).

Compression strength

Figure(8) shows relation between compression strength and wt.% of SiC reinforcement content in AMCs, it is observed that the compression strength of the AMCs increases with increasing wt.% of SiC reinforcement . This is because SiC being strong material added to aluminum which require high strength to compress the AMCs. This analysis is in a good agreement as comparison with(K Karvani , D Fasnakis , [2016]).

CONCULUSIONS

In the present study, AMCs of varying wt.% of SiC (0, 3, 6 and 9 wt.%) were fabricated by using stir casting technique. Microstructural aspects, tensile strength, compression strength, hardness and wear resistance for the prepared composites were studied; depend on experimental evaluation led to following conclusion.

1- Dependence on stir casting technique was successfully in fabricating Al-SiC composites.
2- The microstructural showed clustering and impartially distribution of SiC particles in Al matrix, and increase porosities with SiC content increasing.
3- Wear resistance of AMCs increase with increasing wt.% of SiC reinforcement.
4- It was found that the hardness of the composites increasing with increasing wt.% of SiC reinforcement.
5- It was revealed that the tensile and compression strength increasing with wt.% of SiC reinforcement increase

Table 1 Composition of Al used as matrix material (wt.%)

Element	Fe	Si	Mn	Cu	Mg	Al
Wt.%	0.16	0.19	0.01	0.01	0.01	Balance

Table 2 Composition of mixture for each composite

Matrix	Reinforcement wt%
Al -100%	SiC - 0%
Al-97%	SiC -3%
Al -94%	SiC - 6%
Al -91%	SiC -9%

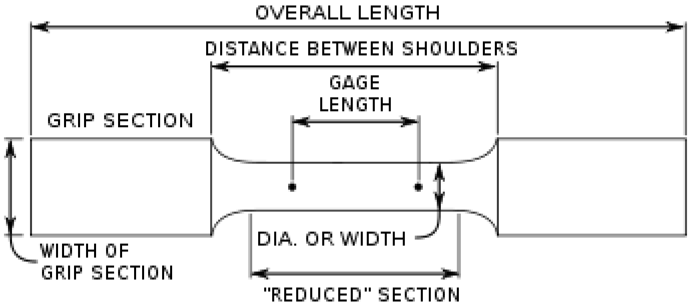


Fig.1 Tensile Test Specimen as per ASTM Standard

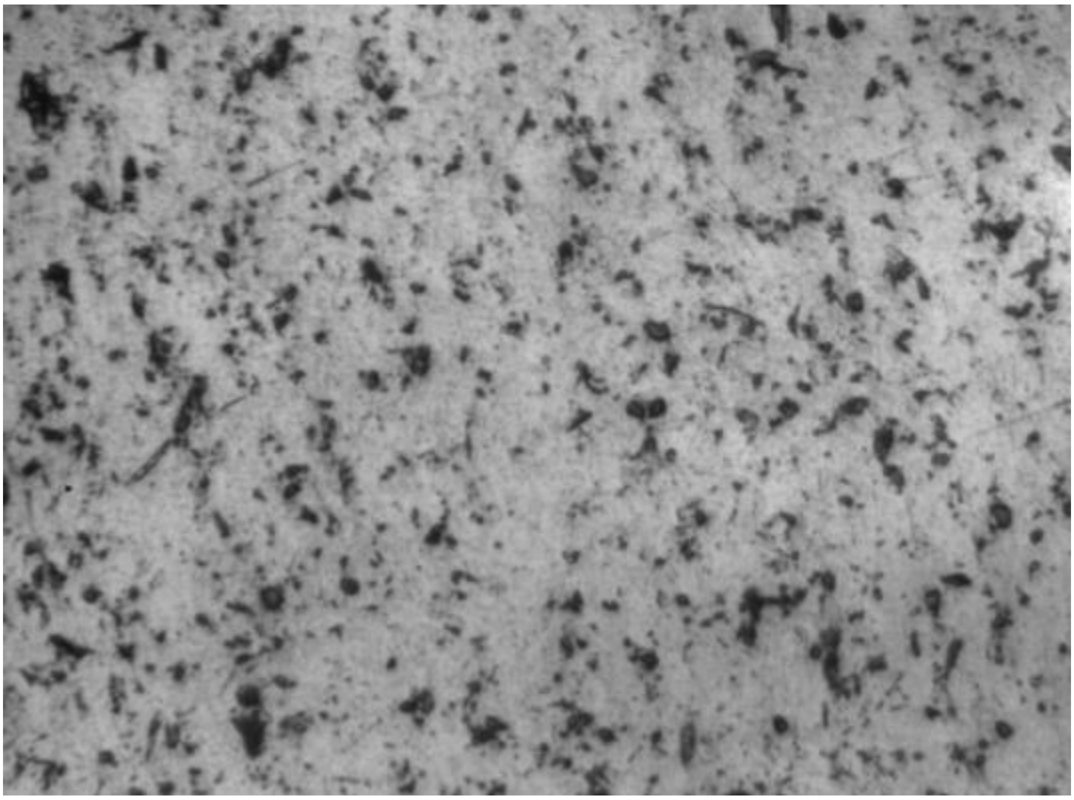


Fig.2 Microstructure of 3 wt. % SiC reinforced AMCs

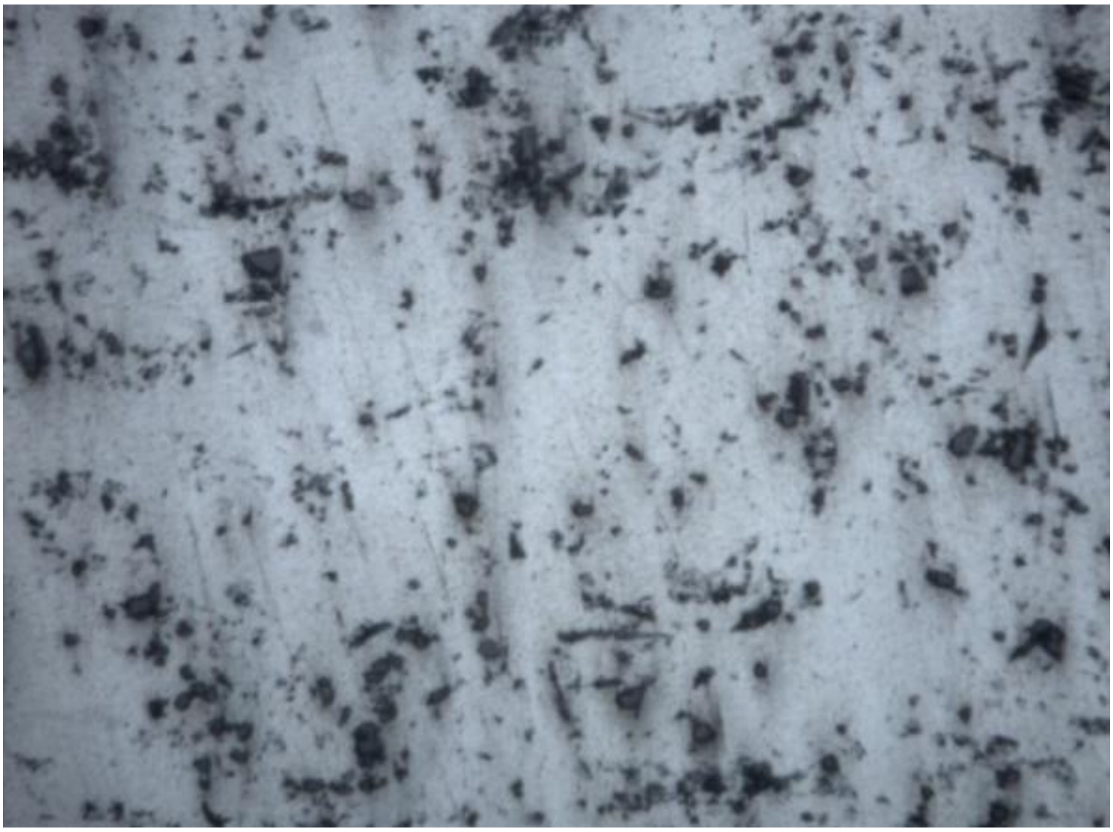


Fig.3 Microstructure of 6 wt. % SiC reinforced AMCs

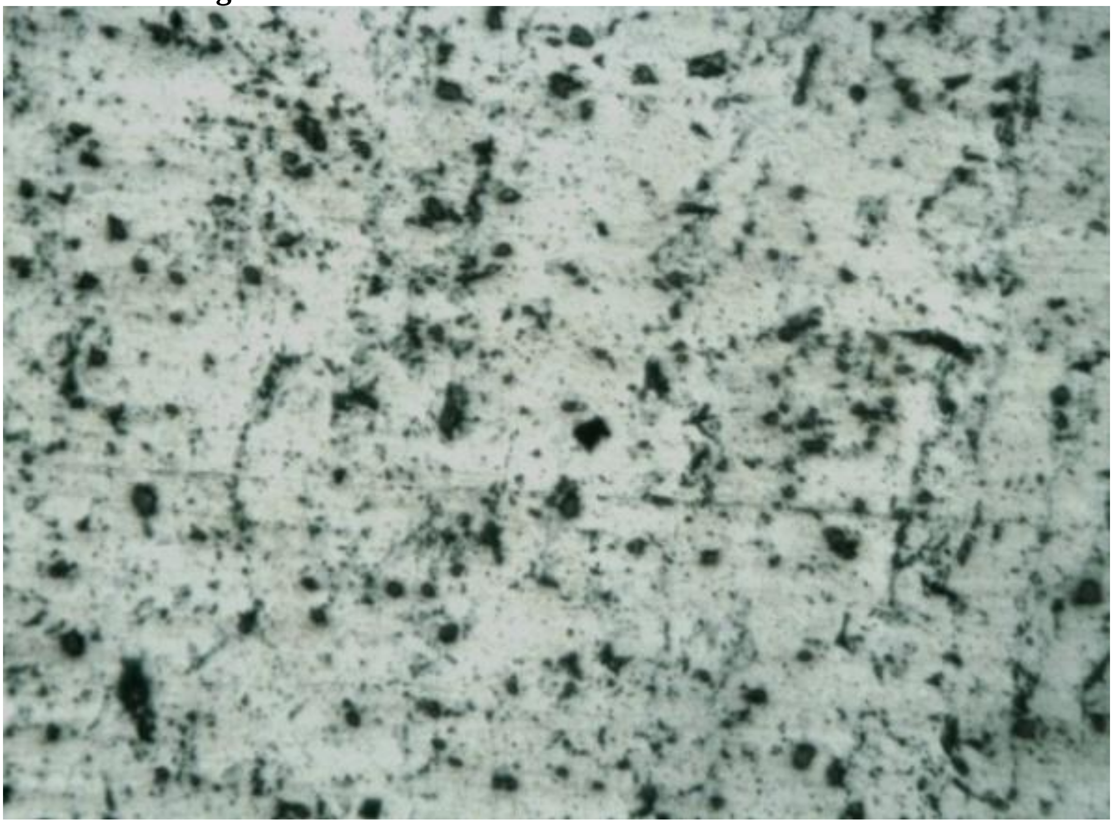


Fig.4 Microstructure of 9 wt. % SiC reinforced AMCs

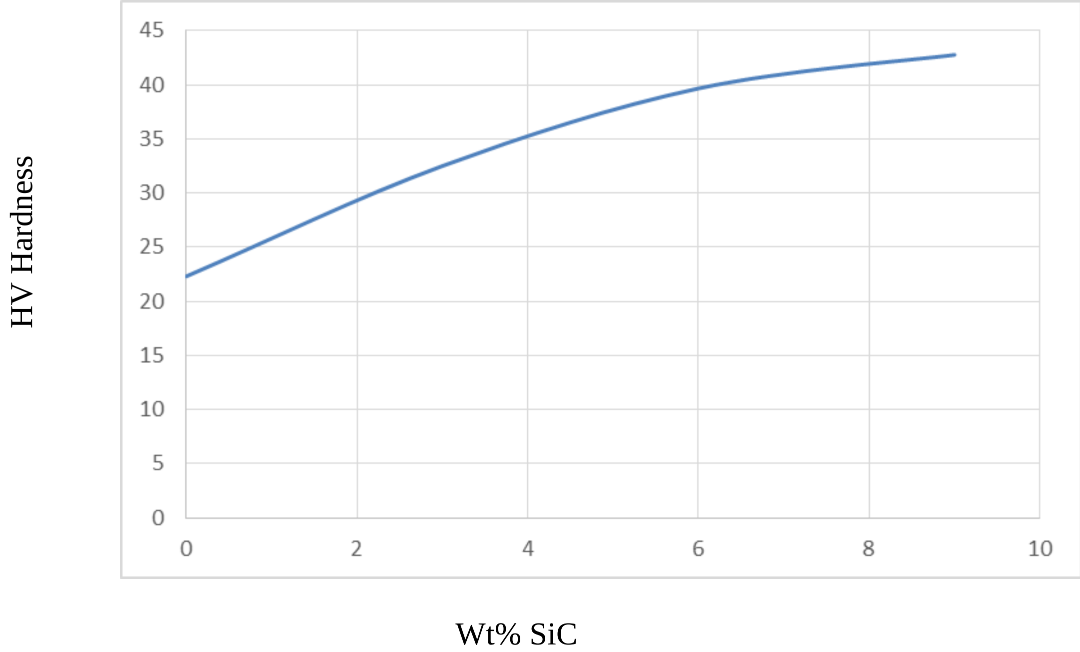


Fig.5 The effect of SiC reinforced AMCs o hardness

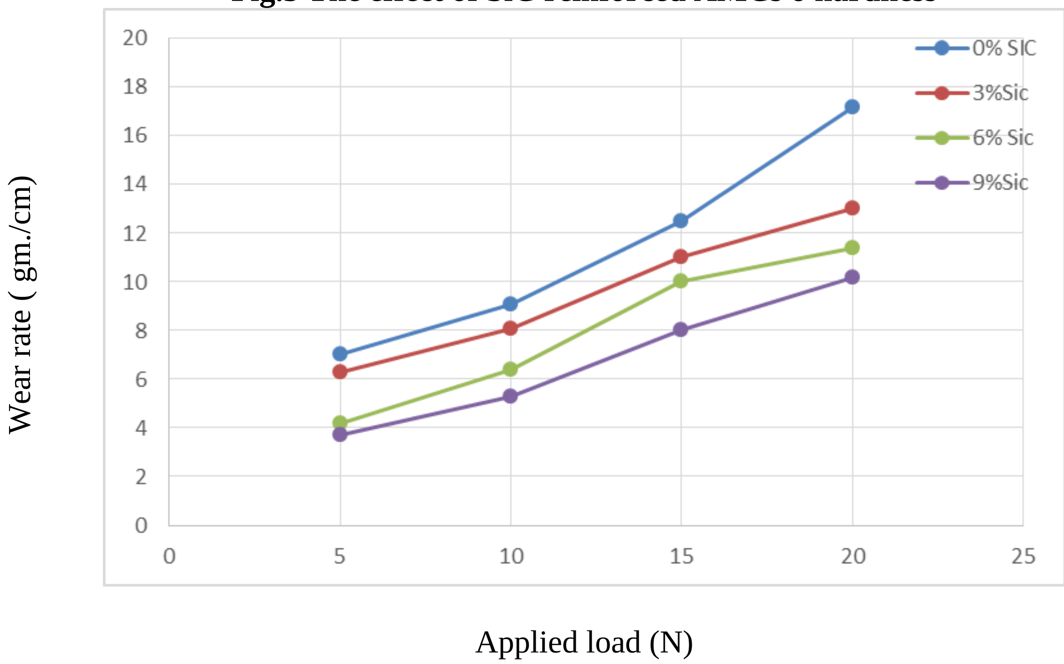
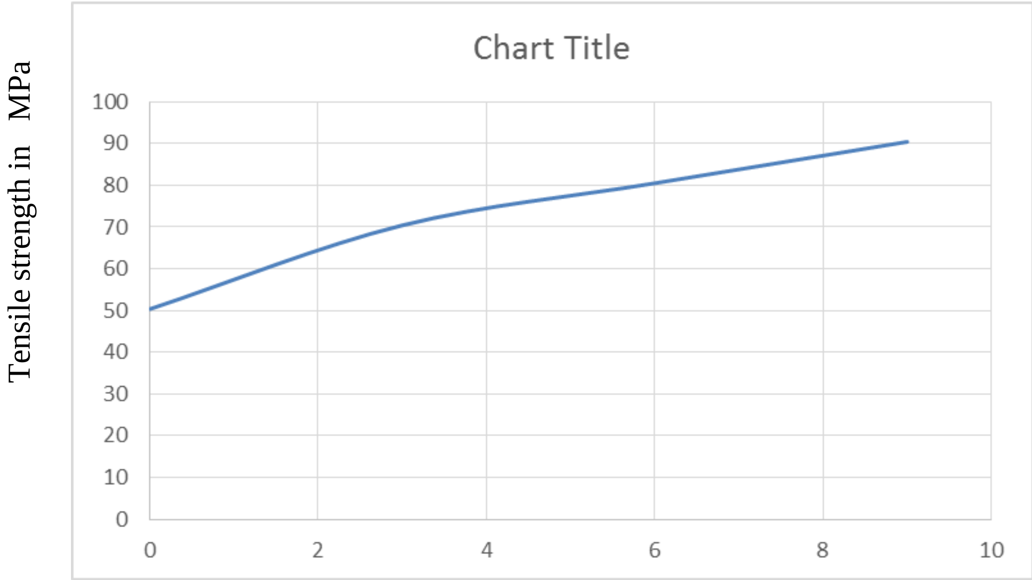
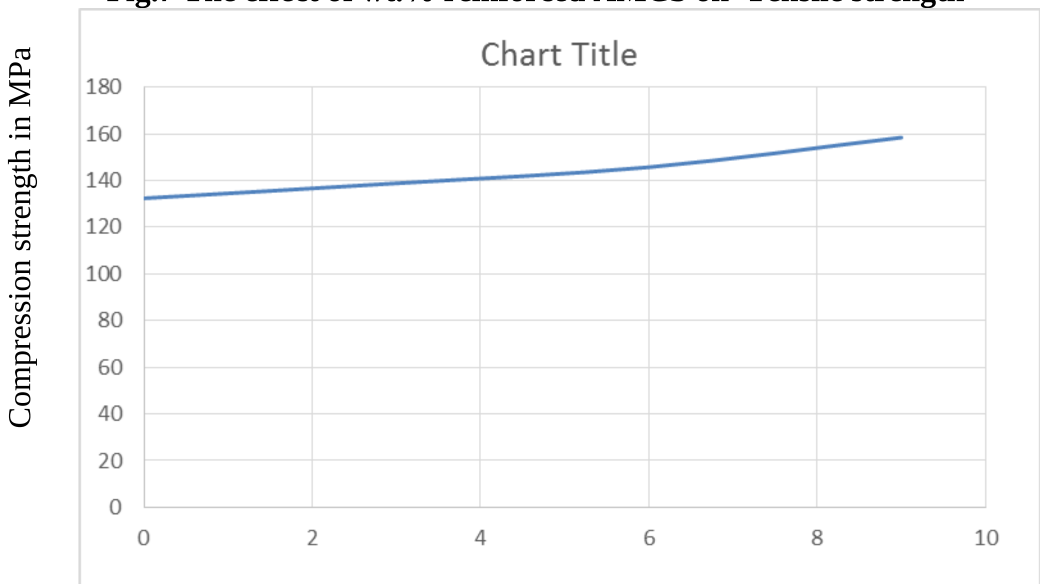


Fig. 6 The effect of wt.% SiC reinforced AMCs on wear rate



Wt. % SiC

Fig.7 The effect of wt.% reinforced AMCS on Tensile strength



Wt%Sic

Fig.8 The effect of wt.% SiC reinforced AMCS on compression strength

REFRENCES

A.Vencl, A.Rac.IBobic, (2004)"Tribologyical behavior of AL-based Mmcs and their applications in automotive industry", Tribol Ind Vol.26,No. 3&4 pp31-38

B.Vijaya Ramanth, C. Elanchezhian, (2014)"Aluiminum Metal matrix composite-Areview" REV.ADV.mater. Sci, Vol.38 pp. 55-60

C.parswajinan, Bvijaya ramnath,(2018)" Hardness and impact behavior of aluminum metal matrix composite" IOP conf. series: materials science and engineering Vol.390 pp. 1-6

G.G.Hosamani, Vishalb.msnoji,(2016)"Characterization of silicon carbide reinforced aluminum matrix composites by using stir casting method" international journal of mechanical and production engineering , ISSN:2320-2092 pp. 85-89

J.Jebeen Moses,I.Dinaharan,(2014)"Characterization of silicon carbide particulate reinforced AA6061 aluminum alloy composite produced via stir casting "international conference on advances in manufacturing and materials engineering AMME pp.106-112

K Karvani , D Fasnakis , (2016)"Production and mechanical properties of Al-SiC metal matrix composites" IOP conf. series: materials science and engineering Vol.161. pp.1-8

Madeva Nagara, Bharath V.,(2013)"Effect of AL2O3 particles on mechanical and wear properties of 6061 AL alloy matrix composites",J.Mater SCI.Vol 2 . PP. 1-4.

Manoj single, D.Deepak dwivedi , (2009)"Development of aluminum based silicon carbide particulate metal matrix composite" journal of minerals & material characterization & engineering vol.8,No.6 pp.455-467

Md.Habibur Rahman, H.M.Mamum ALRashed, (2014) "Characterization of silicon carbide reinforced aluminum matrix composite" 10^{th} international conference on mechanical engineering, ICME pp. 103-109

Muna K. Abbass, Khairia S.Hassan, and Abbas S.Alwan, (2015)"Study of Corrosion Resistance of Aluminum Alloy 6061/SiC Composites in 3.5%NaCl Solution"International Journal of Materials, Mechanics .Vol.3, No1, pp.31-35.

Muna K. Abbass,(2009) "Study of Dry Sliding Wear Behavior of Al-12% Si alloy Produced By Squeeze Casting", The Iraqi Journal For Mechanical And Material Engineering. Vol.19, No.3, pp.369-382.

Muna K. Abbas, Khairia, (2017)"Wear Behaviour of Al-SiC Alloy Matrix Composites Reinforced with SiC Partical" , Association of Arab Universities Journal of Engineering Sciences No. 2, Vol. 24, pp27 -42

Nvmurthy, Aprasad reddy,(2016)"Preparation of sic based aluminum metal matrix nano composites by high intensity ultrasonic cavitation process and evaluation of mechanical and tribological properties"IOP conf. series: materials science and engineering Vol.390 pp.1-6

Pavitra ajagol, Anjanbn , (2018)" Effect of sic reinforcement on microstructure and mechanical properties of aluminum metal matrix composite" IOP conf. Series: materials science and engineering Vol.367. No 1. pp. 1-9

Pradyumna Phutane, Vijay kumars,(2013) "Synthesis and characterization of sic reinforced HE-30 AL alloy particulate MMCS" international journal of engineering and technology Vol. 5, No.3 pp. 2866-2870

Raminder singh bhaia, Kudlipsingh,(2017)" An experimental analysis of aluminum metal matrix composite using Al2O3/B4C/Gr particles" international journal of advanced research in computer science Vol. 8, No 4. pp.83-90

Sadayo pamp, Harish karthi Natarajan (2018) "Study of silicon carbide reinforced aluminum matrix composite brake rotor for motorcycle application"Int J Manuf Technol Journal , Vol. 94. No.1 pp1461 - 1475.

Suryanray anank., R. Praveen, (2013)"Silicon carbide reinforced aluminum metal matrix composite for aerospace application-a literature review" international journal of innovative research in science engineering and technology Vol. 2, No11. pp. 6336-6344