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EFFECT OF SIC PARTICULATE REINFORCEMENT ON FATIGUE AND SHEAR RESPONSE OF AL-CU PISTON ALLOY METAL MATRIX COMPOSITES

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ABSTRACT

The effects of SiC particulate reinforcement on fatigue, impact strength, hardness, tensile and shear response of Al-Cu piston alloys have been investigated. Permanent steel mold was used to cast the specimen in which 0 vol%, 5 vol%, 10 vol%, 15 vol%, 20 vol%, 30 vol%, 40 vol% and 50 vol% additions of SiC were made. The cast specimens were then machined to the required dimensions for the various test carried out. The avery dimension 7305 machine was used for the fatigue tests, horizontal charpy method was used for the impact tests, the Vickers testing machine was used for the hardness test, the hounsefield tensometer was used for tensile testing, and the punch machine was used for shear tests, finally, the scanning electro-microscope was used for the micrographs. The 20 vol% addition gave the best fatigue strength. The impact strength and hardness increased as the additions increased. The result for the tensile strength showed that strength increase up to a maximum of fat 20 vol% addition and then started to decrease. The shear strength increased up to a maximum at 30 vol% addition of SiC before it started decreasing. Scanning electron microscope observations of the microstrutures revealed uniform distribution of particles and in some small areas agglomeration of particles and porosity. In general 20 vol% addition of SiC gave the best mechanical property. The findings may be profitable applied in the fabrication of engine piston where a marked improvement in the durability is required.

KEYWORDS: Al-Cu-piston alloy, SiC particulate, metal matrix composites, permanent mould casting.

INTRODUCTION

There are many situations in engineering where no single structural material can on its own, fully meet the requirement of a particular process design and often, a combination of two or more materials provide a lasting solution to the material selection problem. One of the constituents may, for example, be light and strong but too brittle to be used effectively while the other may be tough and ductile but without sufficient strength. Thus, it is not surprising that, when suitably combined, the above constituents would form a composite with superior properties. Such ingenious combinations in metals, ceremics, concrete, polymers, fibres and wood have provided new structural materials for the engineering and construction industries.[1] The concept of composite material is, however, not new. Ancient China produced the first laminated Archery bows. The use of straws for the strengthening of mud bricks also dates back to ancient civilizations. Generally, the best combination of strength and ductility is achieved in solids which consist of fibres or precipitated particles embedded in ductile host materials, called the matrix. Essentially, the matrix has two primary functions, namely: it disperses the fibre (or particles) uniformly so that dislocations or cracks cannot easily move or propagate through the materials, and it binds the fibre (or particle) together so that the load can be effectively transferred to them.[2] The greatest reinforcing effect is obtained when the fibres are continous and parallel to one another, and the maximum strength is obtained when the composite is stressed in tension, parallel to the fibres.[3]

Statement of Problem

Due to rapid advances in the use of hardenable alloys, some of these alloys may be hardened but have little strength beyond the initial onset of failure hence the need for reinforcing particle that could enhance their mechanical properties of fatigue, strength, hardness and resistance to corrosion, so as to have large deformations and reserve energy absorbing capacity past the onset of failure.

OBJECTIVES OF THE STUDY

It is the objective of this investigation to : develop and demonstrate, at pilot scale, efficient and economic method of processing composite that are representative of the geometries and properties required to meet the performance requirements of potential end use applications.

Significance of the Study

Aluminum is one of world's most abundant metals and the third most common element; hence, its study will create better utilization of the earth endowments. Additionally, in the transportation industry, where there is increasing need for low weight, high strength and hard structural part, a composite of a light weight material like aluminum will be of immense importance. It is hoped that this report gives some awareness of complexity of materials selection problems and necessity for considering the variations in fibre and matrices that are available and the mixture that can be made with blends to leave a very broad range of properties that can be designed into a composite structure.

Scope of the Study

Permanent mode method of casting was used to produce the specimens which were then subjected to fatigue, impact strength, hardness, tensile strength and shear strength tests. Metallographic studies were also done. The present study endeavors to develop a new engine piston material with an improved fatigue life and strength by incorporating SiC particulate reinforcement into the Al-Cu alloy matrix.

Requirement of a Composite Material

The physical properties of composite materials are generally not iso tropic (independent of direction of applied force) in nature, but rather are typically orthotropic (different, depending on the direction of the applied force or load). For instance, the stiffness of a composite panel will often depend upon the orientation of the applied force and/or moments.[4]

Insight into Al Alloys, Al-Cu Alloys, Al-Cu-Mg Alloys and SiC. Related Works in This Area

2.1.0 Aluminum alloys with a wide strange of properties are used in engineering structures. The strength and durability of aluminum alloys vary widely, not only as a result of the components of the specific alloy, but also as a result of heat treatments and manufacturing processes. A lack of knowledge of these aspects has from time to time led to improperly designed structures and has gained aluminum a bad reputation.[5]

One important structural limitation of aluminum is the fatigue strength. Unlike steels aluminum alloys have no well define fatigue limit, meaning that fatigue failure will eventually occur under even very small cyclic loadings. This implies that engineers must access loads and design for a fixed life rather than an infinite life.[6]

Another important property of aluminum alloy its sensitivity to heat. Workshop procedures involving heat are complicated by the fact that aluminum, unlike steel will melt without first glowing red. Forming operations where a blow torch is used, therefore requires some expertise, since no visual signs reveal how close the material is to melting. Aluminum alloys like all structural alloys, also are subject to internal stresses following heating operations such as welding and casting. The problem with aluminum alloys in this regard is the low melting point, which makes them more susceptible to distortion from thermally induced stress. Controlled stress relief can be done during manufacturing by heat treating the parts in an oven, followed by gradual cooling-in effect annealing to relieve the stresses..The low melting point of aluminum has not precluded their use in rocketry; even for use in constructing combustion chambers where gases can reach 3500k. The agama upper stage engine used a regeneratively cooled aluminum design for some part of the nozzle, including the thermally critical throat region.[7]

Al-Cu alloys- Copper ranks as the most important alloying element in Al. Its effect is to decrease shrinkage and hot-shortness and to provide a basis for age – hardening in many aluminum alloys. It is added in amount up to 6% in wrought alloys and up to 10% in cast alloys.[8]

Al-Cu-Mg alloys- Addition of Magnesium to Aluminum –Copper alloys greatly accelerate ductility and intensify precipitation hardening in the system. These alloys were the first precipitation hardenable alloys discovered.[9]

Silicon Carbide properties

Silicon carbide exists in at least 70 crystalline forms. Alpha Silicon carbide (a-SiC) is the most commonly encountered polymorph, it is formed at temperature greater than 200˚C and has hexagonal crystal structure (similar to wurtzik). The beta modification (B-SiC), with a face-centered cubic crystal structure (similar to diamond and zincblende or sphalerite), is found at temperature below 2000˚C. Until recently, the beta form has had relatively few commercial uses, although there is new increasing interest in its use as a support for heterogeneous catalysts, owing to its higher surface area compared to the alpha form.

Silicon carbide has a specific gravity of 3.2, and its high sublimation temperature (approximately 2700˚c) make it useful for bearings and furnance parts.

Silicon carbide does not melt at any known pressure. It is also highly inert chemically.

There is currently much interest in its use as a semiconductor material in electronics, where its high thermal conductivity and high maximum current density make it more promising than Silicon for high powered devices. In addition, it has strong coupling to microwave radiation and together with its high melting point, permits its practical use in heating and casting metals. Sic also has a very low coefficient of thermal expansion and experiences no phase transitions that would cause discontinuities in thermal expansion.

Pure Sic is clear. The brown to black colour when from the industry result from iron impurities. The rainbow like luster of the crystals is caused by a passivation layer of silicondioxide that forms on the surface.[10]

2.2.0 Related works- A study has been made of the mechanized role of silicon Carbide (SiC) particles during fatigue crack propagation in powder metallurgy.

Al-Zn-Mg-Cu metal matrix composites reinforced with 22% vol% Sic particulates. Sic sub (p), with varying sizes of reinforcement phase. Crack growth and accompanying crack tip shielding (Principally by crack deflection, closure and bridging) are examined in peak aged alloys over a wide spectrum of growth rates from 10 super (-12) to 10 super (-4)m in cycle super (-1) and are compared with corresponding behavior in the unreinforced matrix alloy. Crack growth resistance in the composites is found to be superior to that of the unreinforced alloy. The particle size dependence of fatigue strength was clearly seen at ambient temperature, which becomes small at 150˚C and almost disappeared at 250˚C. Crack Initiation depended on temperature and particle size and small crack growth rates were an order faster at 250˚C than at ambient temperature and 150˚C in all materials studied. It was indicated that the softening and associated loss in strength of the matrix at elevated temperature were the primary causes for the observed temperature and particle size dependence of fatigue behavior.[11]

Previous work on tensile and impact strength

The evolution of the microstructure and mechanical properties of a 21.5 vol% SiC particulate– reinforced Al alloy 6092 matrix composite has been studied as a function of post fabrication processing and heat treatment. It is demonstrated that, by the control of particulate distribution, matrix grain, and substructure and matrix precipitate state, the tensile and impact strength combination in the composite can be optimized over a wide range of properties without resorting to unstable, under aged matrix microstructure, which are usually deemed necessary to produced a higher fracture toughness than that displayed in the peak-aged condition. Further, it is demonstrated that, following an appropriate combination of thermomechanical processing and unconventional heat treatment, the composite posses better stiffness, strength and fracture toughness than a similar unreinforced alloy. In the high and low strength matrix microstructural conditions, the matrix grain and substructure were found to play a substantive role in determining fracture properties. However, in the intermediate strength regime, properties appeared to be optimizable by the utilization of heat treatments only. These observations are rationalized on the basis of current understanding of the grain size dependence of fracture toughness and the detailed microstructural features resulting from thermomechanical treatments.[12]

MATERIALS AND METHODS

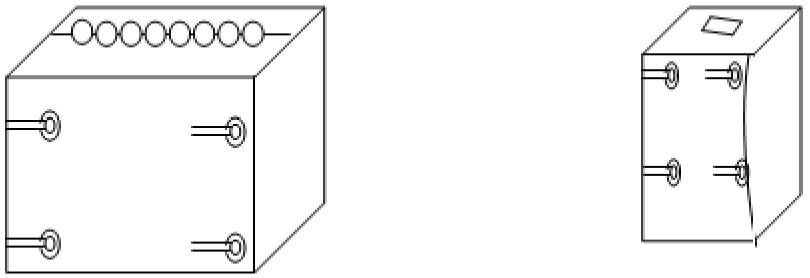
Collection of Materials

The Sic powder was got from a chemical shop in United Kingdom, the pure Al in wire form and Mg in powdered form were got from a science equipment shop in Enugu. The Cu in rod form was purchased from Head Bridge market in Onitsha, Anambra State.

Method: The sample specimens used were prepared at the foundry of Projects Development Agency (PRODA) Enugu. The crucible was mounted at the center while the blower was situated near the base of the furnace. In between the furnace and the crucible, charcoal was stacked and the blower placed in position. A day before the melting, the furnace was relined and allowed to dry properly. The following steps were taken to ensure proper and effective working of the furnace.

1) Ensuring that all cracks on the walls of the furnace were all closed.
2) Ensuring that slags that close the tuyeres of the furnace were all removed.
3) Ensuring that there were no traces of water/moisture within the furnace.

Mould Preparation: The mould used in his work was made especially for the casting of test samples. A permanent mould made of steel was used. The steel mould in rectangular form, had eight holes each of 125mm diameter and 10cm length for each percent addition that needed to be made. The rectangular mould was cut vertically through its center to make two equal halves. This was done in order that the molten metal which would be poured into it could easily be removed after solidification. However, the two halves of the mould can easily be assembled using nuts to bolt them and can be dismounted when necessary. A different permanent mold was also done for the impact strength test specimen. It measured 1.25cm by 1cm and 10cm high. The products were then used for the fatigue test, impact text, hardness test, tensile and shear strength tests. The microstructural examination using seaming electron microscope (SEM) was also done.



(a) (b)

Figure 1: Permanent mould for casting specimen.

a) Fatigue, hardness, tensile, and shear test.

b) Impact test.

3.1.3 Change Calculation

Master alloy 222: 10%Cu, 0.25% Mg (Balance Al)

Density of Master alloy (222)

$$= \frac{Wt}{Vol} = 10gmcu) + 0.25\ (gmMg) + 89.75\ (gmAl)$$

$$= \frac{10}{8.9\ (Cm^3cu)} + \frac{0.25}{1.7(cm^3Mg)} + \frac{89.75}{2.7\ (cm^3Al)\ P}$$

$$= \frac{100}{1.1236 + 0.1471 + 33.2407} = \frac{100}{34.5114}$$

$$= 2.8976gm/cm^3$$

Computation of wt.% from Vol% reinforcement

$$Wt\%\ reinforcement = \frac{Wt.\ of\ reinforcement}{Wt\ of\ reinforcement + Wt\ of\ matric} \times 100$$

$$= \frac{PVp \times 100}{PVp \times PVm}$$

(Where *Pp Vp* = density and Volume%) of particles, and *Pm Vm* = density and Volume % of matric *Pp Vp*

$$\frac{Pp\ Vp}{PpVpt + Pm\ (100 - Vp)}$$, assuming total volume base of 100%

Estimate of materials required for impact test casts

Approximate volume of 8 specimens

$8 \times \frac{\Pi (1.25)^2}{4} \times 10 \quad = 98.17cm^3$

For impact test = 1.25 x 1.x 10

= 12.5cm

Total = 98.17 + 12.5 = 10.67cm

For master alloy (222) this volume would weigh about 320.677g

So for the samples we base the total weight of composite requirement on the figure of 330g.

Test procedures

After casting the following tests were carried out on the casts.

1. Fatigue test
2. Impact test
3. Hardness test
4. Tensile test
5. Shear test
6. Metallographic test

Fatigue – This is the process whereby an already machined samples is fractured value to failure by the application of a known value of reversal stresses which could be equal or unequal in magnitude in both directions (positive and negative). The essence of this is to determine the actual lead the materials in question can withstand before failure in service.

Machine Type – The avery dension 7305 fatigue machine was used. The revolution machine counter filled to the meter recorded the number of cycles to failure. When the specimen breaks, cut out switches attached to the machine stops the machine automatically. It is calculated for the different moments and the results are shown in Table 1.

Impact Test:- The essence of this test is to find out the strength which the material posed at fracture which tries to resist the impact. This gives an idea of the impact strength that a material must have in order to function effectively ads a component of a system.

Machine Type:- The impact test was conducted using the horizontal charpy method. The charpy specimen was plead horizontally and at right angle to the direction of the hammer. The results of the impact test is shown in Table 3.

Hardness Test:- Hardness is defined as the resistance of a surface to absnasion or indentation. The concept of measuring hardness is based on this definition.

Machine Type:- For this work, Vickers testing machine which has a microscope with objective 1½" and a load of 20kg. The specimen was polished to make the dent visible under the microscope. The mean of the values of two dents was taken to get a more accurate value. The result of hardness is shown in table 3.

Tensile Test:- This is the commonly used technique for evaluating the strength and ductility of metals. During tensile testing the specimen is gradually pulled (loaded in tension) and allowed to extend progressively in length under the influence of the applied load, while the magnitude of each applied load and the corresponding extension are recorded continuously. Finally, the cracks propagate under the influence of the applied tensile stress causing fracture.

Machine Type:- The Hounsfield tensometer was used to obtain the tensile strength of the specimens being studied. The results of the tensile test is shown in table 4**.**

The Shear Test:- Shear strength in Engineering is a term used to describe the strength of a material or component against the type of yield or structural failure where the material or component fails in shear. Ultimate strength of a material subjected to shear loading if the maximum shear stress that can be sustained by a material before rupture. For this work the punch shear test was used.

Machine Type:- The punch shear machine was used. A graph sheet is put in place and as the specimen is being punched. The graph plots until it gets to the maximum shear strength, it then stops and punching also stops. The results of the shear tests is shown in Table 5.

Metallographic Test

The specimen was placed flat on the microscope and held firm using a clip. Magnifications ranging from 400kx to 500kx were used. Under vacuum the specimens were bombarded with finely focused beam of electrons. Electromagnetic coils deflect the beam and cause it to scan across the specimen surface. Secondary electrons were emitted from the surface under bombardment and were converted into signal used to build the image on a cathode ray tube.

Scanning Electron Microscope: A scanning electron microscope (STM) is a type of electron microscope that images a sample by scanning it with a high energy beam of electrons in a master scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the samples surface topography, composition and other properties such as electrical conductivity. The images got from 0%, 5%, 10%, 15% and 20% sic additions are displayed on plated 1, 2, 3, 4, 5

5.0.0 RESULTS

5.1.0 Fatigue Test

Table 1: Fatigue Test for SiC Addition.

0% SiC		5% SiC		10% SiC		15% Sic	
Stress	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**
181.5	1.781	180.5	2.151	178	2.333	180	2.553
153.1	1.891	152.1	2.001	150	2.255	156	2.538
120.2	1.911	120	2.302	126.2	2.293	117	2.677
79.3	2.233	86.91	2.241	95.8	2.641	92	2.911
52.1	3.551	60.1	3.455	60.3	4.000	74	4.131
42.8	4.813	48	4.811	52.4	5.110	60	5.523
38.4	6.319	42.1	6.211	50.2	6.331	56	6.855
35.1	7.441	40	7.441	49.1	7.388	55	7.598

0% SiC		5% SiC		10% SiC		15% Sic	
Stress	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**
176.7	2.810	179	1.255	182.3	1.000	179.8	0.881
140.8	2.844	152	1.266	153.1	1.085	154.3	0.930
90.2	3.252	120	1.388	120.5	1.211	125.00	1.004
80.4	3.933	83	1.771	72.5	1.833	87.79	1.243
76.5	5.00	52	3.455	42.3	3.211	41.38	2.531
74.6	5.8314	38	4.889	35.3	4.800	29.40	4.112
73.4	6.555	35	6.318	34.1	6.220	22.31	5.633
72.2	7.410	32	7.661	30.3	7.430	20.00	7.680

Table 2: Fatigue statistical description by one way anova of SiC percentage addition.

					95% Confidence Interval for Mean	
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
0%	3	1.8610	.07000	.04041	1.6871	2.0349
5%	3	2.1513	.15050	.08689	1.7775	2.5252
10%	3	2.2937	.03900	.02252	2.1968	2.3906
15%	3	2.5893	.07629	.04405	2.3998	2.7789
20%	3	2.9687	.24596	.14201	2.3577	3.5797
30%	3	1.3030	.07382	.04262	1.1196	1.4864
40%	3	1.0987	.10616	.06129	.8349	1.3624
50%	3	.9380	.06239	.03602	.7830	1.0930
Total	24	1.9005	.70756	.14443	1.6017	2.1992

Descriptives Sic

	Minimum	Maximum
0%	1.78	1.91
5%	2.00	2.30
10%	2.26	2.33
15%	2.54	2.68
20%	2.81	3.25
30%	1.26	1.39
40%	1.00	1.21
50%	.88	1.00
Total	.88	3.25

Anova Sic

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.283	7	1.612	111.158	.000
Within Groups	.232	16	.015		

Table 3: Instrumental Variable Regression Modeling of Fatique Data For Sic Percentage Additions.

ANOVA

Sic

	Sum of Squares	df
Total	11.515	23

Post Hoc Tests

Multiple Comparisons

Sic
LSD

(I) %	(J) %	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
0%	5%	-.29033*	.09832	.009	-.4988	-.0819
	10%	-.43267*	.09832	.000	-.6411	-.2242
	15%	-.72833*	.09832	.000	-.9368	-.5199
	20%	-1.10767*	.09832	.000	-1.3161	-.8992
	30%	.55800*	.09832	.000	.3496	.7664
	40%	.76233*	.09832	.000	.5539	.9708
	50%	.92300*	.09832	.000	.7146	1.1314
5%	0%	.29033*	.09832	.009	.0819	.4988
	10%	-.14233	.09832	.167	-.3508	.0661
	15%	-.43800*	.09832	.000	-.6464	-.2296
	20%	-.81733*	.09832	.000	-1.0258	-.6089
	30%	.84833*	.09832	.000	.6399	1.0568
	40%	1.05267*	.09832	.000	.8442	1.2611
	50%	1.21333*	.09832	.000	1.0049	1.4218
10%	0%	.43267*	.09832	.000	.2242	.6411
	5%	.14233	.09832	.167	-.0661	.3508
	15%	-.29567*	.09832	.008	-.5041	-.0872
	20%	-.67500*	.09832	.000	-.8834	-.4666
	30%	.99067*	.09832	.000	.7822	1.1991
	40%	1.19500*	.09832	.000	.9866	1.4034
	50%	1.35567*	.09832	.000	1.1472	1.5641
15%	0%	.72833*	.09832	.000	.5199	.9368
	5%	.43800*	.09832	.000	.2296	.6464
	10%	.29567*	.09832	.008	.0872	.5041
	20%	-.37933*	.09832	.001	-.5878	-.1709
	30%	1.28633*	.09832	.000	1.0779	1.4948
	40%	1.49067*	.09832	.000	1.2822	1.6991
	50%	1.65133*	.09832	.000	1.4429	1.8598
20%	0%	1.10767*	.09832	.000	.8992	1.3161
	5%	.81733*	.09832	.000	.6089	1.0258
	10%	.67500*	.09832	.000	.4666	.8834
	15%	.37933*	.09832	.001	.1709	.5878
	30%	1.66567*	.09832	.000	1.4572	1.8741
	40%	1.87000*	.09832	.000	1.6616	2.0784
	50%	2.03067*	.09832	.000	1.8222	2.2391
30%	0%	-.55800*	.09832	.000	-.7664	-.3496
	5%	-.84833*	.09832	.000	-1.0568	-.6399
	10%	-.99067*	.09832	.000	-1.1991	-.7822
	15%	-1.28633*	.09832	.000	-1.4948	-1.0779
	20%	-1.66567*	.09832	.000	-1.8741	-1.4572
	40%	.20433	.09832	.054	-.0041	.4128
	50%	.36500*	.09832	.002	.1566	.5734
40%	0%	-.76233*	.09832	.000	-.9708	-.5539
	5%	-1.05267*	.09832	.000	-1.2611	-.8442
	10%	-1.19500*	.09832	.000	-1.4034	-.9866
	15%	-1.49067*	.09832	.000	-1.6991	-1.2822
	20%	-1.87000*	.09832	.000	-2.0784	-1.6616
	30%	-.20433	.09832	.054	-.4128	.0041
	50%	.16067	.09832	.122	-.0478	.3691
50%	0%	-.92300*	.09832	.000	-1.1314	-.7146
	5%	-1.21333*	.09832	.000	-1.4218	-1.0049
	10%	-1.35567*	.09832	.000	-1.5641	-1.1472
	15%	-1.65133*	.09832	.000	-1.8598	-1.4429
	20%	-2.03067*	.09832	.000	-2.2391	-1.8222
	30%	-.36500*	.09832	.002	-.5734	-.1566
	40%	-.16067	.09832	.122	-.3691	.0478

*. The mean difference is significant at the 0.05 level.

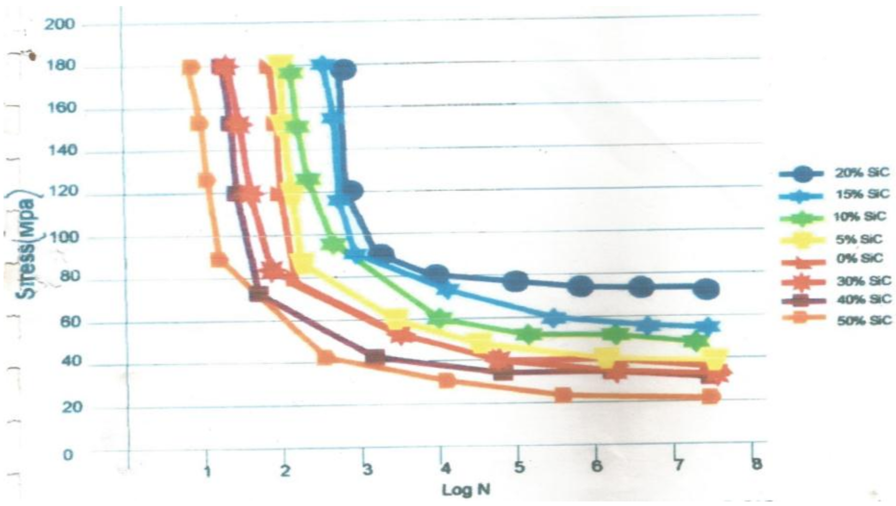


Figure 2: The S-N Diagram for all the percentage additions of SiC.

Xtreg stress logn lognsq ,fe i(id) (Instrumental Variable Regression)

Fixed-effects (within) regression			Number of observed	=	64
Group variable (i): id			Numbers of groups	=	8
R-sq:	within	=0.8107	Observed per Group: min	=	8
	between	=0.9196	Average	=	8.0
	overall	=0.6150	maximum	=	8
			F(2,54)	=	115.64
	Corr(u_i, Xb)	= -0.3804	Prob>F	=	0.0000

Stress	Coef.	Std. Err	T	P>|t|	[95% Conf. Interval]
logn lognsq _cons	-69.47475 5.714579 245.6515	7.755179 .8747954 13.76018	-8.96 6.53 17.85	0.000 0.000 0.000	-85.02295 -53.92656 3.960719 7.468438 218.064 273.239

Sigma_u Sigma_e rho	26.303326 24.043551 54479387 (fraction of variance due to u _i)

Prob > F=0.0000

5.2.0. IMPACT TEST RESULT

Impact Test Result for SiC

Table-4.

SiC %	Impact strength (J/cm2)10
0	8.35
5	8.7
10	10
15	12.0
20	14.8
30	30.1
40	32.2
50	33.4

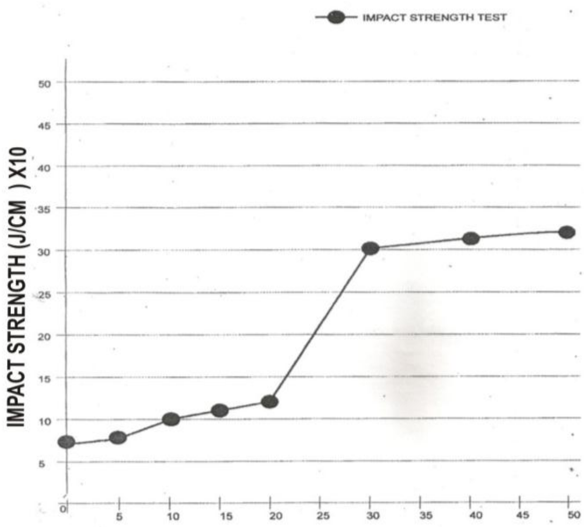


Figure 3: A plot of impact strength against vol.% of SiC adde.

Hardness Test Result

Hardness Test Result for SiC additions

Table-5.

SiC	Vickers Pyramid Number (VPN)		
0	18.9	20.9	19.9
5	20.4	22.8	21.6
10	25	23.4	24.2
15	25	25	25.0
20	27.1	25.3	26.2
30	29	29.6	29.3
40	33.1	32.7	32.9
50	34	34	34

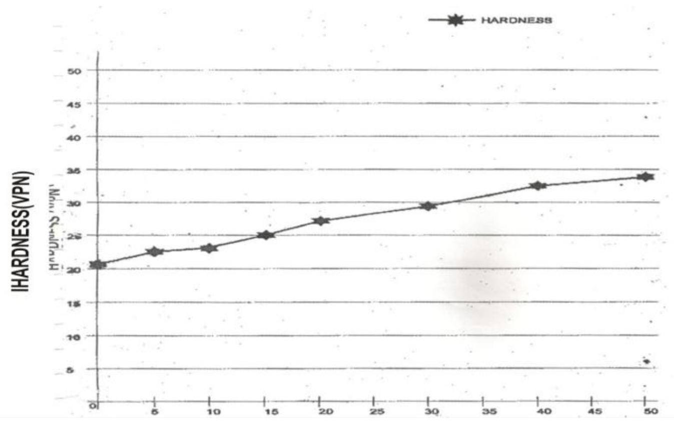


Fig 4: Aplot of hardness against vol. % of SiC added.

Tensile Test Result

Tensile Test Result for SiC additions

Table-6.

% SiC added	Fracture Load (N)	Total Extension (mm)	% Elongation	% Reduction Cross Sectional	Ultimate Tensile Strength (N/mm²)
0	1,570	8.15	18.1	30.0	25.0
5	2,350	11.25	21.4	30.0	33.5
10	2,400	11.45	23.1	30.0	42.0
15	2,500	11.85	25.0	32.0	47.9
20	2,700	14.50	26.3	32.0	51.7
30	2,700	14.60	30.4	42.0	47.5
40	2,690	13.50	32.2	43.0	41.8
50	2,690	14.63	36.2	45.0	31.0

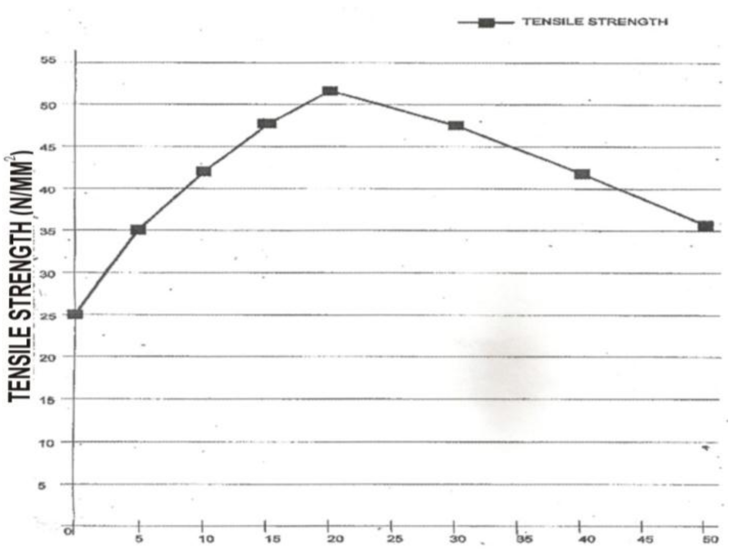


Figure 5: A plot of Tensile strength against vol.% of SiC added.

Shear Test Result

Shear Test Result for SiC additions

Table-7.

% of SiC added	Shear strength N/mm²
0	20.5
5	25.75
10	29.6
15	36.5
20	39
30	41.8
40	37.25
50	27.5

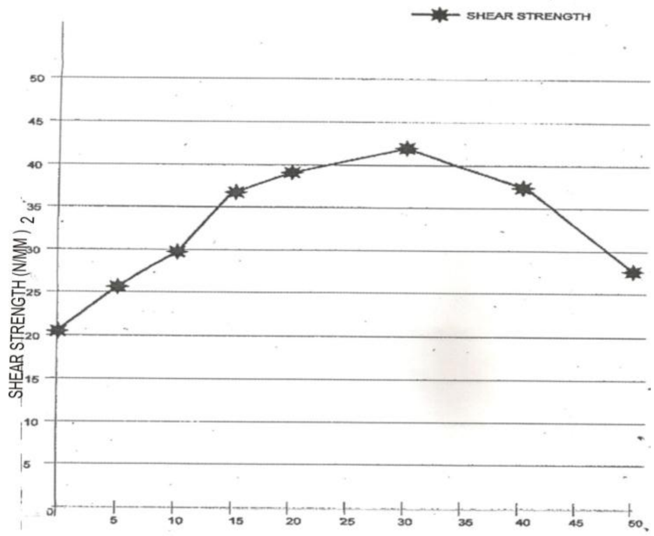
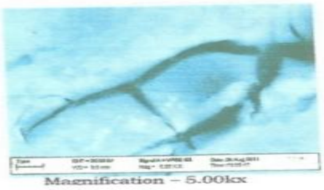


Figure 6: A plot of shear strength against vol.% of SiC added.

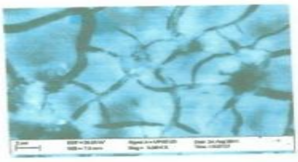
5.4.0METALLOGRAPHIC TEST:

5.6.1 METALLOGRAPHIC TEST RESULTS:



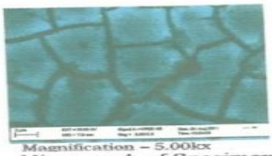
Magnification – 5.00kx

Plate 1 MICROGRAPH of Specimen with 0% SiC Addition



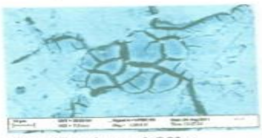
Magnification – 5.00kx

Plate 2 Micrograph of Specimen with 5% SiC addition



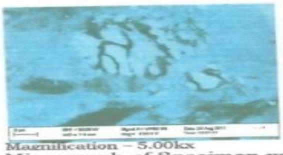
Magnification – 5.00kx

Plate 3 Micrograph of Specimen with 10% SiC addition



Magnification – 4.00kx

Plate 4 Micrograph of Specimen with 15% SiC addition



Magnification – 5.00kx

Plate 5 Micrograph of Specimen with 20% SiC addition

Plate 1: Micrograph of specimen with 0% SiC addition.

Plate2: Micrograph of specimen with 5% SiC addition.

Plate 3: Micrograph of specimen with 10% SiC addition.

Plate 4: Micrograph of specimen with 15% SiC addition.

Plate 5: Micrograph of specimen with 20% SiC addition.

DISCUSSION

Fatigue Test

Going through the fatigue test tables and the graphs for the different percentages additions of SiC, it was evident that 20% additions gave the best fatigue strength followed by 15% and subsequently by 10% and then by 5% before the one without addition. Those of 30%, 40% and 50% then followed.

One way anova analysis of fatigue

Fatigue having the most disastrous attack on the composites had to be analyzed statistically. The logN of the first three stress values were taken for each percentage addition. The one way anova analysis agreed with the result that the 20% addition gave the best fatigue strength followed by 15%, 10%, 5%, 0%, 30%, 40% and then 50%.

Instrumental Variable Regression Modeling.

Instrumental variable regression modeling of the fatigue figures gave the best model for the fatigue analysis because not only that the probability was significant in all additions. It was also able to give one model for the sets of scatter plots. It also gave the best co-efficient of determination (R) and the fixed effect it showed was similar within and with co-moment additions. Overall quadratic model was got for the additions.

The model appears thus;

Stress = 245.65 – 69.47 log N+57 $(\log N)^2$

Impact Test

The impact Strength increased progressively though not linearly as the percentage additions increased up to the highest percentage given which is 50%.

Hardness Test: The VPN of Al-Cu alloy is lower than those of alloys containing SiC. Starting from 5% addition the VPN values continued to increase up to 50% additions. The increase is not linear but undulating.

Tensile Test:- The tensile strength of the alloys increased progressively with increase in the SiC additions but passed through a maximum at 20% additions and thereafter decreased indicating that the alloys have their plastic deformation in the 20% addition range.

Shear Test:- The shear strength of the alloy increased as the additions were increased but passed through a maximum at 30% addition and thereafter started decreasing.

Metallographic Test

Plate 1: A clear difference is seen in this micrograph from the other ones containing some reinforcement. It is seen to be a single phase except for a localized equiaxed structure probably Cu in the master alloy due to its dark nature.

Plate 2: Under microscopic examination, there observed to be proper dispersion of the Sic added. This can be seen as dark patches on the structure which has more or less equiaxed patches of the contents.

Plate 3: Microstructure of this sample also shows an even dispersion of the SiC throughout the section with an appreciable concentration at the center of the micrograph. The equiaxed grains appear larger than that containing 5% SiC. The concentration of Sic at some parts at the centre of the section can be seen as being darker in that locality whereas the edge of the sample with finer grains richer in Al are shown to be brighter

Plate 4: The micrograph reveals that the precipitates of SiC were not completely disposed as was observed in the last two additions. It clustered more or less in some places though smaller equiaxed structure is still evidence of better hardness and strength.

Plate 5: In this micrograph, the SiC also clustered in some places indicating the increase in mass of the additions. These are seen as some dark patches. At some locations agglomeration of particles and also segregations. The non numerous pores and condensed nature of the structure also reveals it having the best properties.

CONCLUSIONS AND RECOMMENDATION

In conclusion, the results of this work show that

1. Master alloy 222 (10% Cu, 0.25% Mg and balance Al) had the best fatigue strength when reinforced with 20% of SiC.
2. The one way anova analysis of the fatigue figure agreed with that trend.
3. The model for the analysis for fatigue is stress = 254.65 – 69.47logN+5.7 $(\log N)^2$.
4. The impact strength of the master alloy sample increased as the quantity of the SiC added increased up to the maximum.
5. The hardness value of the master alloy sample also increased as the quantity of SiC added increased up to the maximum used.
6. The tensile strength of the master alloy sample increased progressively with increase in the addition of SiC but passed through a maximum at 20% addition and then started decreasing as the weights of the additions increased.
7. The shear strength of the master alloy sample increased with increase in the addition of SiC but passed through a maximum at 30% addition before it started decreasing.
8. The Vicker’s hardness recorded are in good agreement with the impact test results and showed similar trend between the alloys.
9. It was also found that a strong trend or correlation existed between the fatigue tests results and the tensile test results, both of which had the best results at 20% reinforcement concentration. The implications on the structures were highlighted with the electron microscopy.
10. The mocrographs show fairly uniform distribution of SiC particulate in the Al-Cu metal matrix. The microstructure of the composite contained Al dendrites and eutectic Silicon with SiC particles separated at interdendritic regions.
11. Therefore, based on the finding made in this work, I recommend this work to industries and establishments where engine pistonare produced and whose desire is to produce aluminium alloys with good fatigue and shear resistance.

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