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INVESTIGATION OF THE MECHANICAL PROPERTIES OF Al_20_3 REINFORCED Al-Cu PISTON ALLOY METAL MATRIX COMPOSITE

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ABSTRACT

The effects of Al_20_3 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 Al_20_3 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 40 vol% addition of Al_20_3 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 Al_20_3 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, Al_20_3 particulate, metal matrix composite, permanent.

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. The composites posses improved physical and mechanical properties such as superior strength to weight ratio, good ductility, high strength and modulus, low thermal expansion coefficient, excellent wear resistance, corrosion resistance, high temperature creep resistance and better fatigue strength.[1,2] Metal-matrix composite (MMCs) are most promising in achieving enhanced mechanical properties.

Aluminum-matrix composites (AMCs) reinforced with particles and whiskers are widely used for high performance applications such as in automotive, military, aerospace and electricity industries because of improved mechanical properties.[3] Al-Cu piston alloy exhibit moderate strength and is used in automotive applications.[4] The composite formed out of Al alloys are of wide interest owing to their strength, fracture toughness, wear resistance and stiffness. Further, these composites are of superior in nature for elevated temperature application when reinforced with ceramic particle.[5] Several authors reported that particulate reinforced composite exhibit superior mechanical properties compared to unreinforced alloys.

Particulate such as SiC, TiC, and TiB_2, yash have been used to reinforced Al alloys to improved their mechanical properties and wear resistance.[6] Mahendra et al. reported a higher tensile strength and hardness for Al-.4.5% Cu alloy-yash based composite. Kumar et al.[4] in a study on Al 7075-Al_20_3 metal matrix composite concluded that the tensile strength properties of composite are found higher than that of based matrix Al 7075 alloy and also hardness of the composite increased with increased additions. Long et al.[7] reported the tensile strength of the Al 6061-T6 alloy was increased by 20% by the reinforcement with 20 vol% of Al_20_3. Sahin et al.[3] and Mahdavi et al.[8] in their studies of properties of SiC particles reinforced Al alloy composite reported that, wear properties of the Al alloy improved significantly by the addition of SiC particles into the matrix alloy. Strafeini et al.[9] reported that the matrix hardness has a strong influence on the dry sliding wear behavior of 6061Al-Al_20_3 composite. It has been found that reinforcement has a great influence on the properties of the Al metal matrix. The addition of ceramic particles result in increasing the dislocation density and decreasing the grain size of the metal matrix.[10]

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.[11]

Insight into Al alloys, Al-Cu alloys, Al-Cu-Mg alloys and Al_20_3.

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.[12]

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.[13]

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.[14]

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.[15]

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.[16]

Oxide matrix CFCCs (Continous fibre reinforced ceramic composite)

Alumina and mullite matrix CFCCs have been successfully demonstrated in applications where high tolerance to salt corrosion, molten glass or oxidation is required in combination with high toughness, light weight, and high thermal shock resistance, characteristic of CFCCs. Fibers generally used for industrial applications requiring long life include SiC, mullite, or alumina and mullite CFCCs. Processes available to fabricate alumina and mullite matrix CFCCs and matrix compositions formed, include Sol-gel

(Al_20_3, $Si0_2$), directed metal oxidation and chemical bonding. The interface coating varies widely and in some cases is not required, resulting in improved thermal stability but reduced interlamina properties. Material properties of alumina and mullite CFCCs are ultimately determined by the combination of fiber process, and interface coating sizing selected. The applications are in various stages of development, with hot gas filtration being well along in the product development cycle and the nearest to commercialization.

MATERIALS AND METHODS

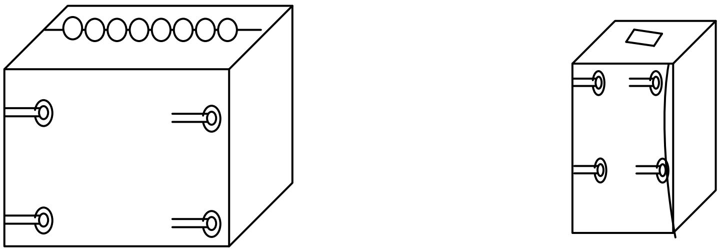
Collection of Materials

The Al_20_3 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

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

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

$$= \frac{PVp \text{ x } 100}{PVp \text{ x } PVm}$$

(Where *Pp Vp* = density and Volume%) of particles, and *Pm Vm* = density and Volume % of matric $\underline{Pp\ Vp}$

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

Estimate of materials required for impact test casts

Approximate volume of 8 specimens

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

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.

RESULTS

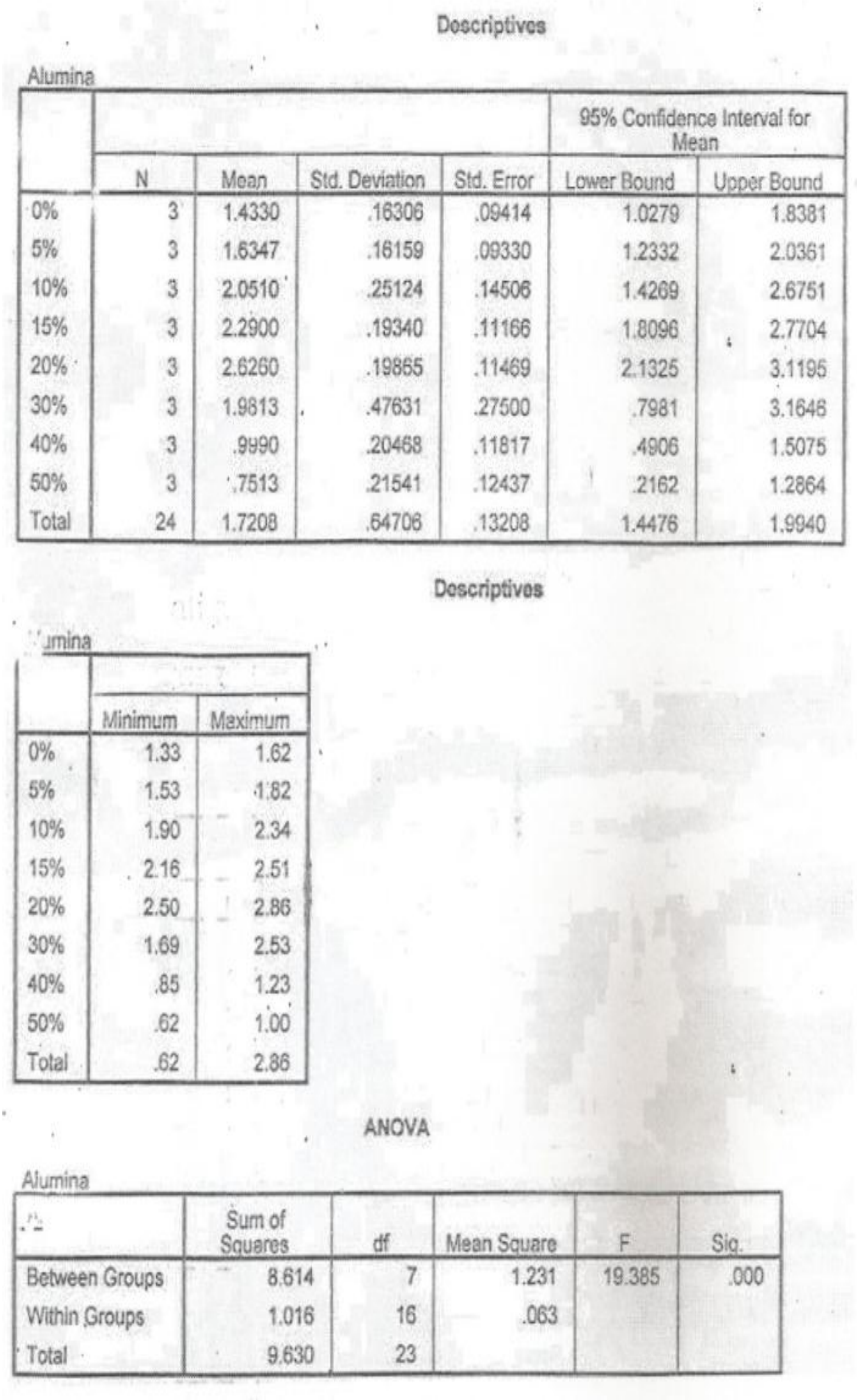
Fatigue Test

Table 1: Fatigue Test for Al_20_3 Addition.

0% Al_20_3		5% Al_20_3		10% Al_20_3		15% Al_20_3	
Stress	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**
179.44	1.333	179	1.533	180	1.899	180	2.158
153.88	1.348	154.31	1.550	150	1.913	152	2.200
96.55	1.621	97.22	1.821	99.99	2.341	94.51	2.512
38.31	3.544	44.31	3.522	59.99	3.532	62.13	3.914
31.83	5.00	36.31	3.455	51.00	4.931	54.31	5.114
29.43	6.355	32.33	6.112	44.11	6.000	52.11	6.200
25.81	7.214	31.44	7.200	43.34	7.128	51.11	7.000
23.18	7.934	30.48	8.000	43.00	8.000	51.00	7.911

Table 2: Fatigue statistical description by one way anova of Al_20_3% addition.

0% Al_20_3		5% Al_20_3		10% Al_20_3		15% Al_20_3	
Stress	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**	**Stress**	**Log N**
181.34	2.523	178	1.690	178	0.8531	180	0.622
148.51	2.500	150	1.723	152.88	0.911	150	0.632
103.41	2.855	100	2.531	94.33	1.233	93.81	1.000
71.23	3.911	52.31	3.641	32.11	3.211	44.31	2.150
62.11	5.521	39.11	4.952	19.33	4.955	17.31	4.231
60	6.101	36.01	6.021	17.88	6.200	10.21	6.021
60	7.000	36.00	7.000	16.81	7.211	10.11	7.213
60	7.812	36.00	7.911	16.12	7.899	9.00	7.891



Descriptives

Alumina

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
0%	3	1.4330	.16306	.09414	1.0279	1.8381
5%	3	1.6347	.16159	.09330	1.2332	2.0361
10%	3	2.0510	.25124	.14506	1.4269	2.6751
15%	3	2.2900	.19340	.11166	1.8096	2.7704
20%	3	2.6260	.19865	.11469	2.1325	3.1195
30%	3	1.9813	.47631	.27500	.7981	3.1646
40%	3	.9990	.20468	.11817	.4906	1.5075
50%	3	.7513	.21541	.12437	.2162	1.2864
Total	24	1.7208	.64706	.13208	1.4476	1.9940

Descriptives

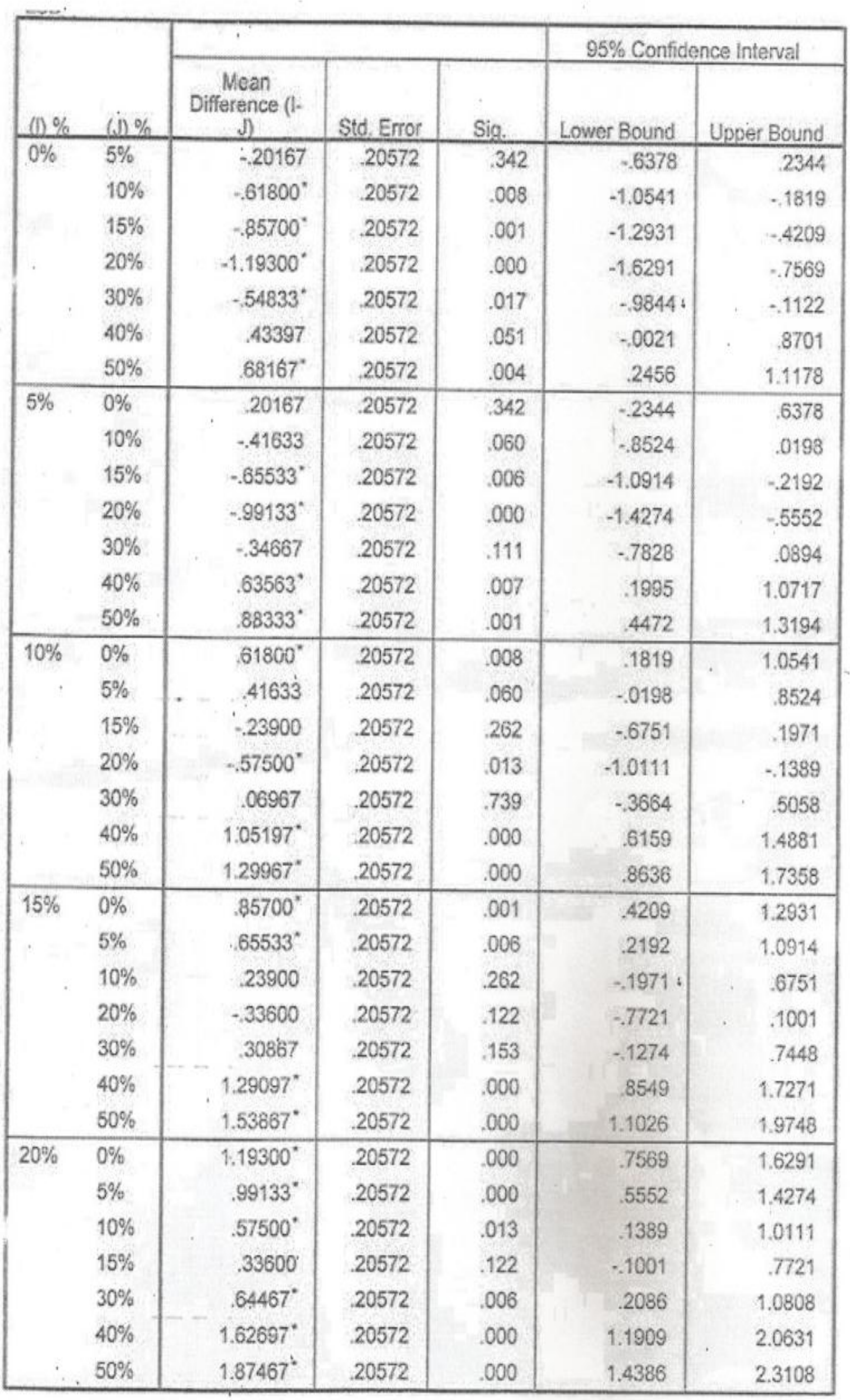
umina

	Minimum	Maximum
0%	1.33	1.62
5%	1.53	1.82
10%	1.90	2.34
15%	2.16	2.51
20%	2.50	2.86
30%	1.69	2.53
40%	.85	1.23
50%	.62	1.00
Total	.62	2.86

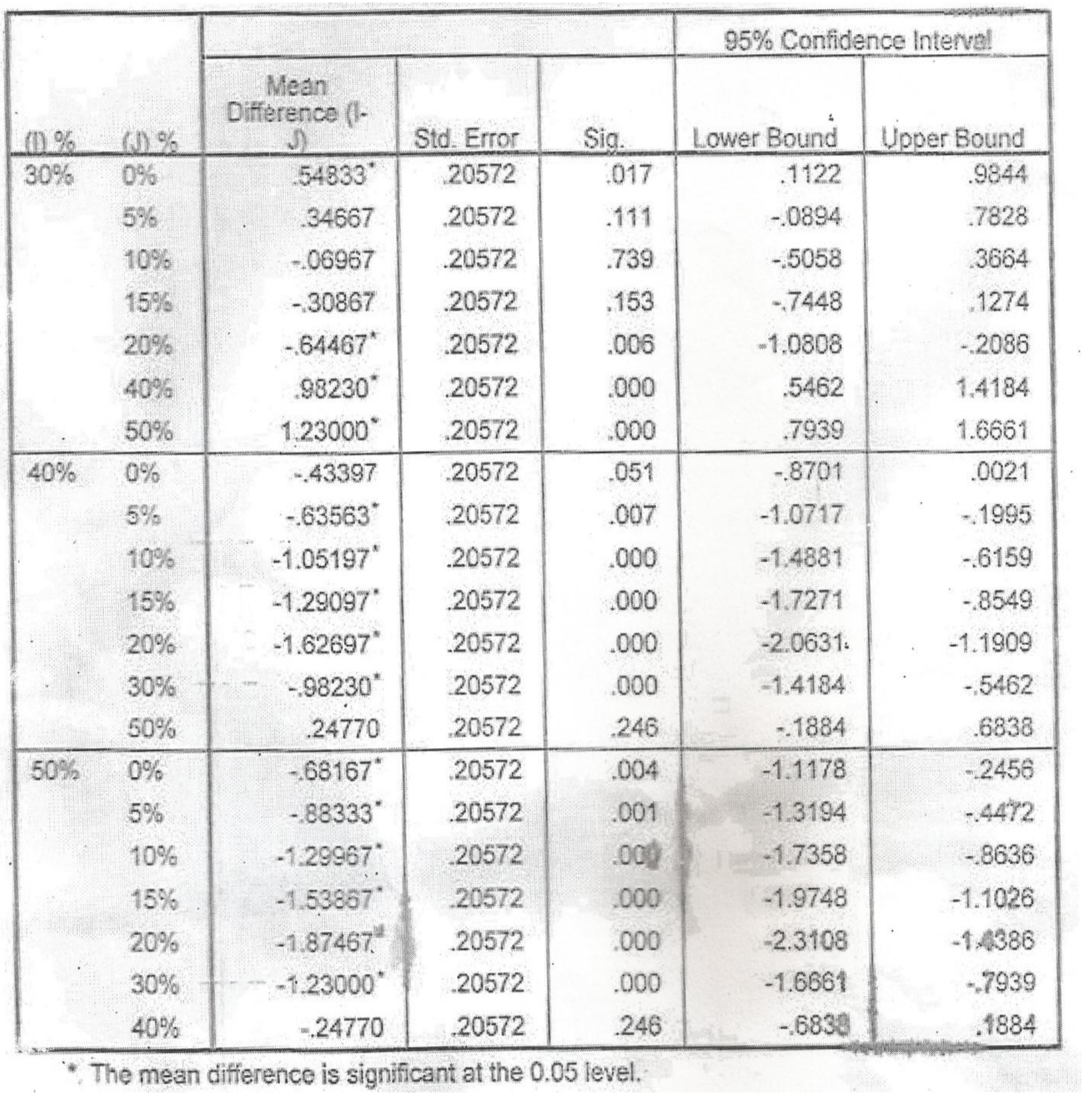
ANOVA

Alumina

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.614	7	1.231	19.385	.000
Within Groups	1.016	16	.063		
Total	9.630	23			



(I) %	(J) %	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
0%	5%	-.20167	.20572	.342	-.6378	.2344
	10%	-.61800*	.20572	.008	-1.0541	-.1819
	15%	-.85700*	.20572	.001	-1.2931	-.4209
	20%	-1.19300*	.20572	.000	-1.6291	-.7569
	30%	-.54833*	.20572	.017	-.9844	-.1122
	40%	.43397	.20572	.051	-.0021	.8701
	50%	.68167*	.20572	.004	.2456	1.1178
5%	0%	.20167	.20572	.342	-.2344	.6378
	10%	-.41633	.20572	.060	-.8524	.0198
	15%	-.65533*	.20572	.006	-1.0914	-.2192
	20%	-.99133*	.20572	.000	-1.4274	-.5552
	30%	-.34667	.20572	.111	-.7828	.0894
	40%	.63563*	.20572	.007	.1995	1.0717
	50%	.88333*	.20572	.001	.4472	1.3194
10%	0%	.61800*	.20572	.008	.1819	1.0541
	5%	.41633	.20572	.060	-.0198	.8524
	15%	-.23900	.20572	.262	-.6751	.1971
	20%	-.57500*	.20572	.013	-1.0111	-.1389
	30%	.06967	.20572	.739	-.3664	.5058
	40%	1.05197*	.20572	.000	.6159	1.4881
	50%	1.29967*	.20572	.000	.8636	1.7358
15%	0%	.85700*	.20572	.001	.4209	1.2931
	5%	.65533*	.20572	.006	.2192	1.0914
	10%	.23900	.20572	.262	-.1971	.6751
	20%	-.33600	.20572	.122	-.7721	.1001
	30%	.30867	.20572	.153	-.1274	.7448
	40%	1.29097*	.20572	.000	.8549	1.7271
	50%	1.53867*	.20572	.000	1.1026	1.9748
20%	0%	1.19300*	.20572	.000	.7569	1.6291
	5%	.99133*	.20572	.000	.5552	1.4274
	10%	.57500*	.20572	.013	.1389	1.0111
	15%	.33600	.20572	.122	-.1001	.7721
	30%	.64467*	.20572	.006	.2086	1.0808
	40%	1.62697*	.20572	.000	1.1909	2.0631
	50%	1.87467*	.20572	.000	1.4386	2.3108



(I) %	(J) %	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
30%	0%	.54833*	.20572	.017	.1122	.9844
	5%	.34667	.20572	.111	-.0894	.7828
	10%	-.06967	.20572	.739	-.5058	.3664
	15%	-.30867	.20572	.153	-.7448	.1274
	20%	-.64467*	.20572	.006	-1.0808	-.2086
	40%	.98230*	.20572	.000	.5462	1.4184
	50%	1.23000*	.20572	.000	.7939	1.6661
40%	0%	-.43397	.20572	.051	-.8701	.0021
	5%	-.63563*	.20572	.007	-1.0717	-.1995
	10%	-1.05197*	.20572	.000	-1.4881	-.6159
	15%	-1.29097*	.20572	.000	-1.7271	-.8549
	20%	-1.62697*	.20572	.000	-2.0631	-1.1909
	30%	-.98230*	.20572	.000	-1.4184	-.5462
	50%	.24770	.20572	.246	-.1884	.6838
50%	0%	-.68167*	.20572	.004	-1.1178	-.2456
	5%	-.88333*	.20572	.001	-1.3194	-.4472
	10%	-1.29967*	.20572	.000	-1.7358	-.8636
	15%	-1.53867*	.20572	.000	-1.9748	-1.1026
	20%	-1.87467*	.20572	.000	-2.3108	-1.4386
	30%	-1.23000*	.20572	.000	-1.6661	-.7939
	40%	-.24770	.20572	.246	-.6838	.1884

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

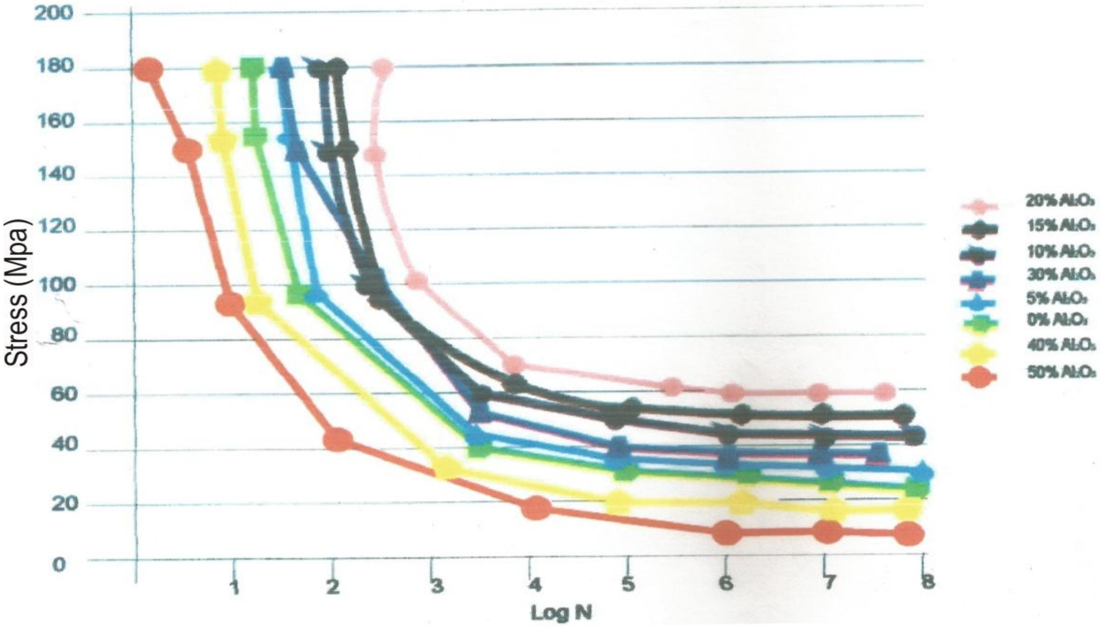
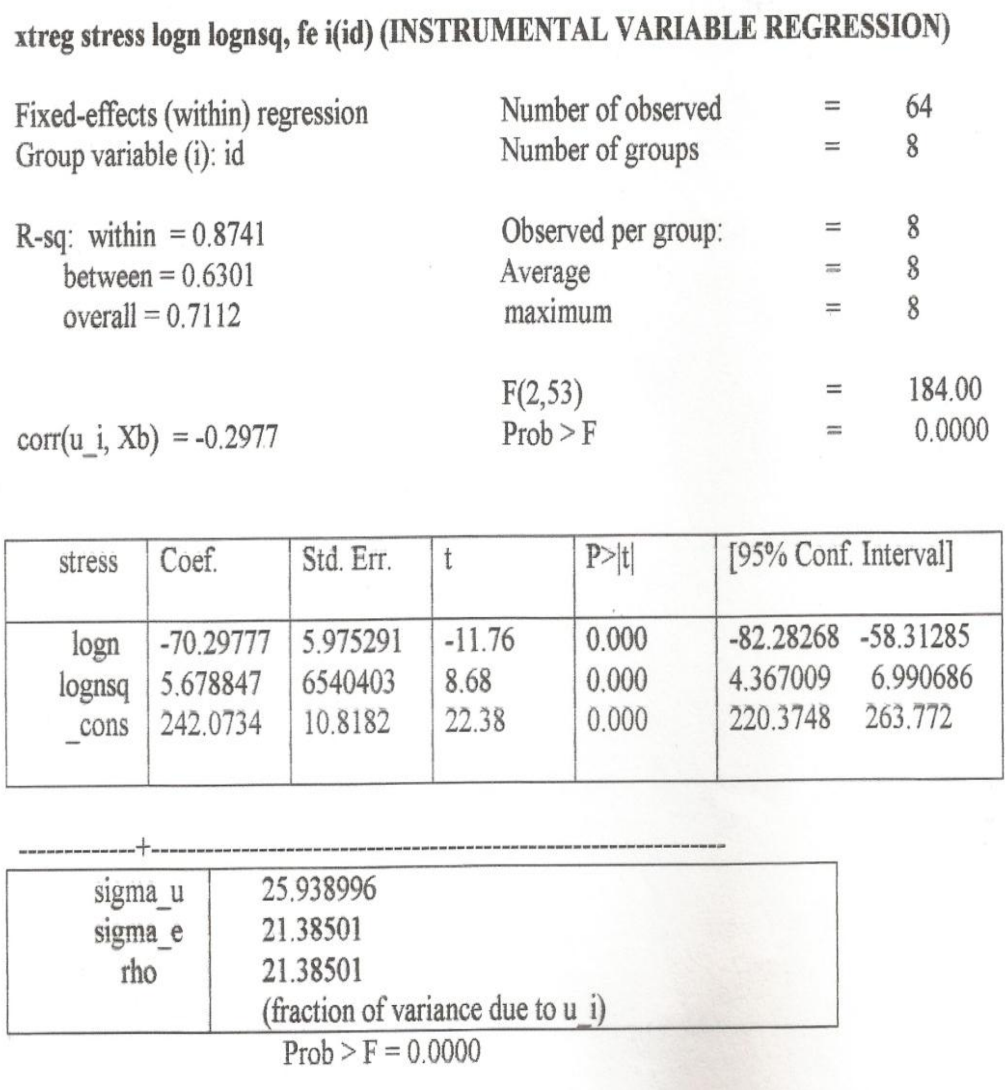


Figure 2: The S-N Diagram for all the percentage additions of Al_20_3.

Table 3: Instrumental variable regression modeling of fatigue data.



```
xtreg stress logn lognsq, fe i(id) (INSTRUMENTAL VARIABLE REGRESSION)

Fixed-effects (within) regression        Number of observed      =    64
Group variable (i): id                   Number of groups        =    8

R-sq:  within  = 0.8741                  Observed per group:     =    8
       between = 0.6301                  Average                 =    8
       overall = 0.7112                  maximum                 =    8

                                         F(2,53)                 =    184.00
corr(u_i, Xb)  = -0.2977                 Prob > F                =     0.0000

   stress | Coef.      Std. Err.   t        P>|t|    [95% Conf. Interval]
----------+-----------------------------------------------------------------
     logn | -70.29777  5.975291    -11.76   0.000    -82.28268   -58.31285
   lognsq | 5.678847   6540403     8.68     0.000    4.367009     6.990686
    _cons | 242.0734   10.8182     22.38    0.000    220.3748     263.772

------------+-------------------------------------------------------------
    sigma_u | 25.938996
    sigma_e | 21.38501
        rho | 21.38501
            | (fraction of variance due to u_i)
               Prob > F = 0.0000
```

Impact Test Result

Table 4: Impact Test Result for Al_20_3

Al_20_3%	Impact strength (J/cm2)10
0	8.0
5	8.5
10	8.9
15	11.5
20	13.0
30	28.0
40	30.5
50	31.0

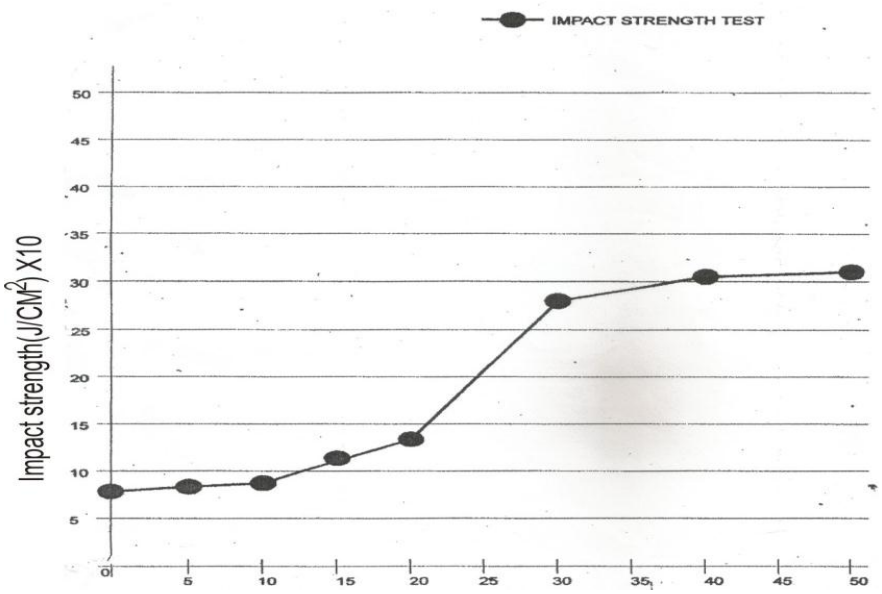


Figure 3: A plot of impact strength against vol.% of Al_20_3 added.

Hardness Test Result

Table 5: Hardness Test Result for Al_20_3 additions.

Al_20_3	Vickers Pyramid Number (VPN)		
0	19.1	17.3	18.2
5	19.0	19.0	19.0
10	20.2	23.2	21.2
15	25.0	23.6	24.3
20	26.1	26.5	26.3
30	29	27.4	28.2
40	31.3	31.3	31.3
50	32.6	33.4	33

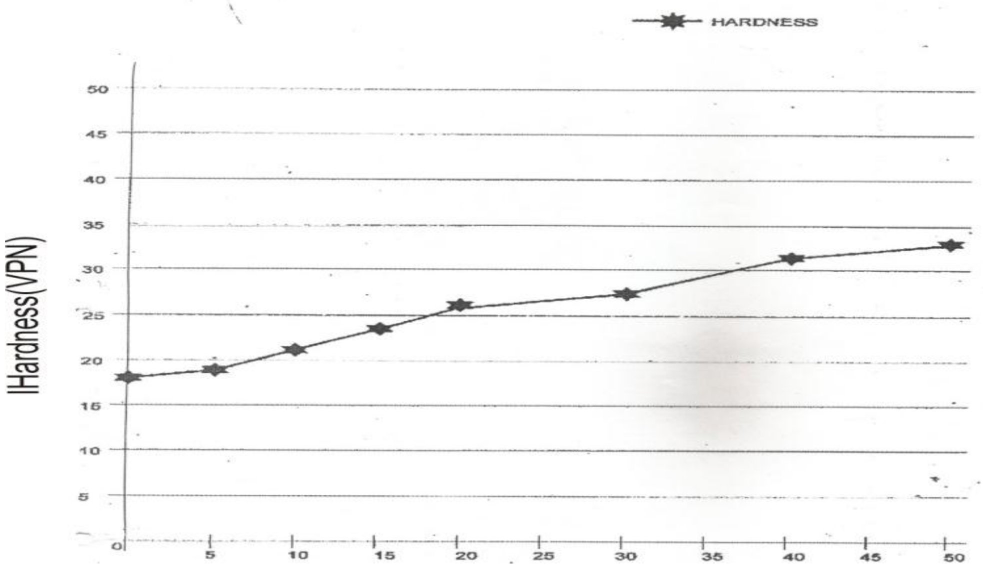


Fig 4: A plot of hardness against vol. % of Al_20_3 added.

Tensile Test Result

Table 6: Tensile Test Result for Al_20_3 additions.

% Al_20_3 added	Fracture Load (N)	Total Extension (mm)	% Elongation	% Reduction Cross Sectional	Ultimate Tensile Strength (N/mm^2)
0	1,538	7.25	16.2	28.0	21.0
5	2,341	9.30	17.2	29.0	30.0
10	2,350	9.40	18.0	30.30	38.0
15	2,400	10.00	20.1	30.40	43.5
20	2,500	11.25	23.4	31.5	48.0
30	2,400	10.20	30.2	33.0	47.5
40	2,450	10.28	31.1	34	42
50	2,450	10.30	31.8	35	45.5

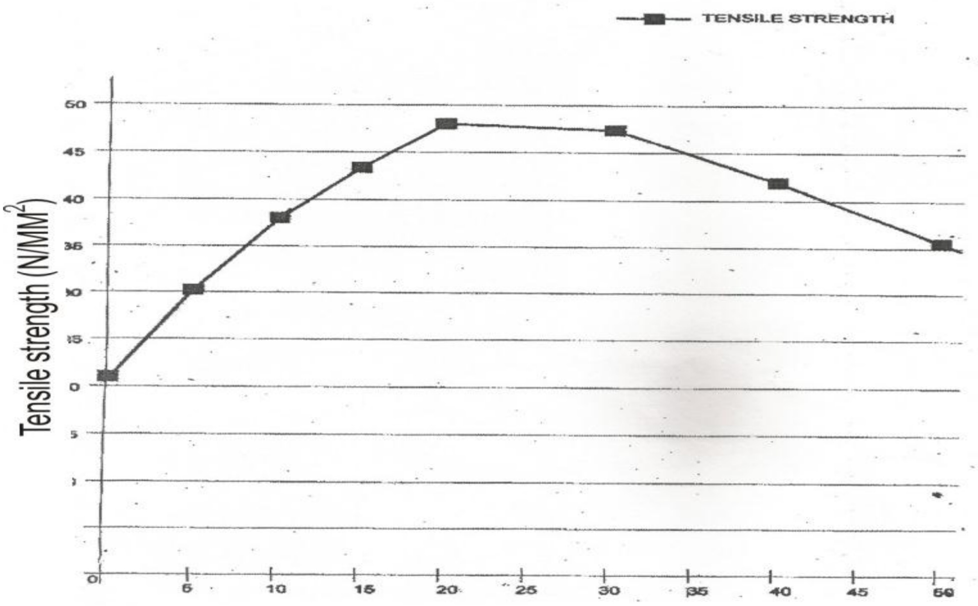


Figure 5: A plot of Tensile strength against vol.% of Al_20_3 added.

Shear Test Result

Table 7: Shear Test Result for Al_20_3 additions.

% of Al_20_3 added	Shear strength N/mm^2
0	16
5	20.5
10	26.5
15	34.7
20	39.5
30	40.4
40	41
50	34

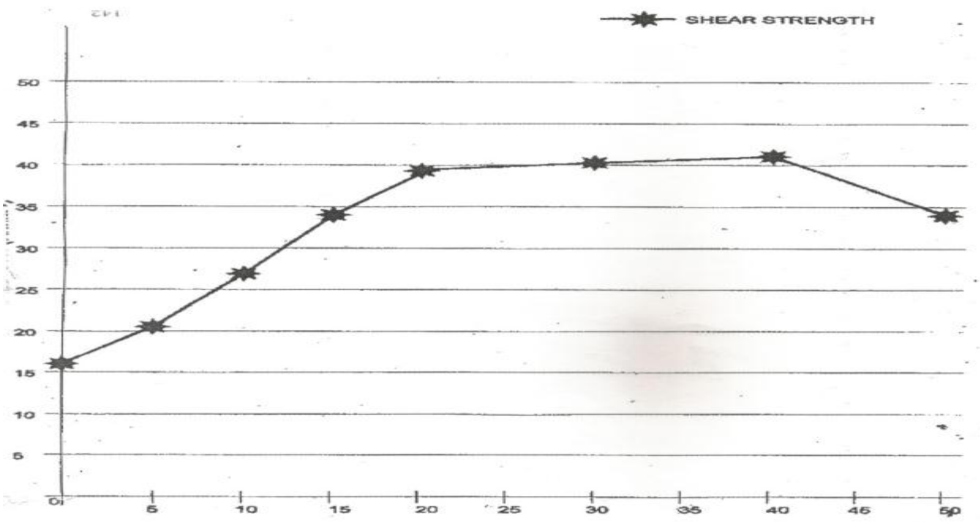
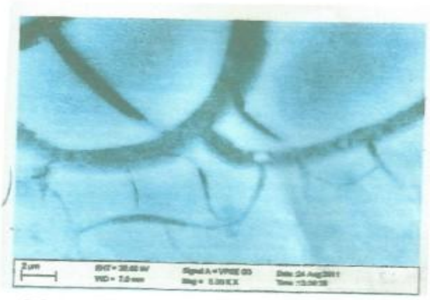


Figure 6: A plot of shear strength against vol.% of Al_20_3 added.

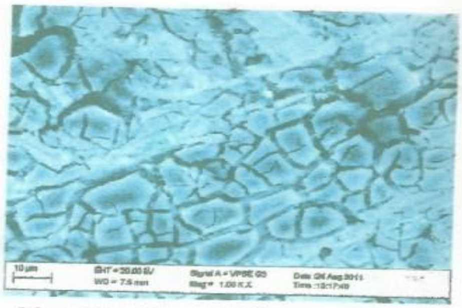


Magnification – 4.00kx

Plate 1: Micrograph of Specimen with 5% Al_2O_3 addition

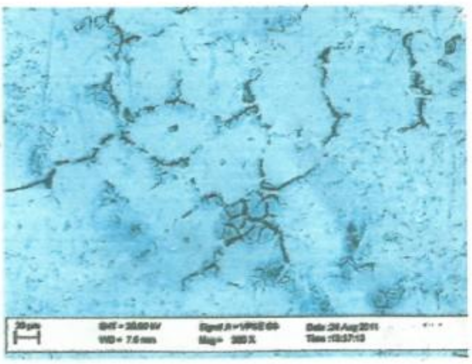
Magnification – 5.00kx

Plate 2: Micrograph of Specimen with 10% Al_2O_3 addition



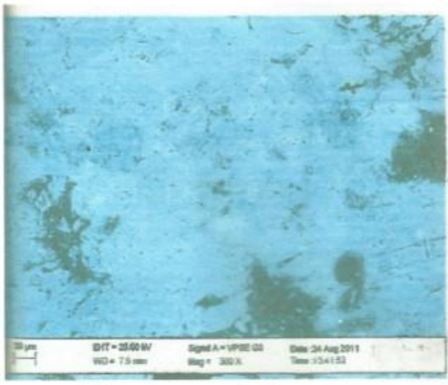
Magnification – 5.00kx

Plate 3: Micrograph of Specimen with 15% Al_2O_3 addition



Magnification – 5.00kx

Plate 4: Micrograph of Specimen with 20% Al_2O_3 addition



Magnification – 5.00kx

Plate 5 Micrograph of Specimen with 30% Al_2O_3 addition

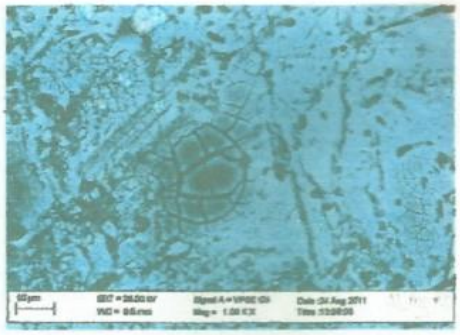


Plate 6: Magnification – 5.00kx

11 Micrograph of Specimen with 40% Al_2O_3 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 Al_20_3, 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 = $242.07-70.30\text{LogN}+5.68\,(\text{LogN})^2$

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 Al_20_3. 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 Al_20_3 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 alloys increased as the additions were increased but passed through a maximum at 40% addition and thereafter started decreasing.

Metallographic Test

Plate 1: This micrograph which shows the 5% addition of Al_20_3 has an appreciable concentration at the upper section. This is shown as dark features. The lower is lighter and has grains more homogeneously distributed is believed to be more of Al.

Plate 2: The micrograph which shows 10 addition of Al203 has even distribution of Al_20_3 in the sample. With each equiaxed structure shown having edges of Al_20_3 and the middle sections being clearer hence containing more Al. The important point is that the grain size is same throughout the entire structure and would therefore give better mechanical properties than that of the 5% addition.

Plate 3: The micrograph of 15% addition shows a homogeneous distribution of the reinforcing material in the matrix. The equiaxed grains observed is even indicating good mixing of the reinforcement and the matrix. This surely would produce good hardness, strength and fatigue properties.

Plate 4: This depicts the structure with 20% Al_20_3 addition. This shows even distribution of the minute equiaxed grains. This shows its better mechanical properties than the previous ones which though are evenly distributed have coarser grains.

Plate 5: This is the micrograph of the structure with 30% addition of Al_20_3. The analysis of this specimen reveals minute equiaxed grains though there are dark patches at the down part and at the left and right edges. These are patches of Al_20_3 due to its increasing mass. Though there are these agglomerates most parts still have evenly distributed grains, which is why this particular specimen gives good shear resistance.

Plate 6: This is the micrograph with 40% addition of Al_20_3. The microstructure has two noticeable constituents. The darker particles are grains of Al_20_3. They are dispersed through a matrix of Al-Cu. The individual grains are seen due to the increasing mass of reinforcement. There is also seen to be a cluster of Al_20_3 at the center of the micrograph. This specimen did not give acceptable mechanical 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 Al_20_3.

2. The one way anova analysis of the fatigue figure agreed with that trend.
3. The model for the analysis for fatigue is stress = 242.07-70.30LogN+5.68(logN)^2.
4. The impact strength of the master alloy sample increased as the quantity of the Al_20_3 added increased up to the maximum.
5. The hardness value of the master alloy sample also increased as the quantity of Al_20_3 added increased up to the maximum used.
6. The tensile strength of the master alloy sample increased progressively with increase in the addition of Al_20_3 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 Al_20_3but 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 Al_20_3 particulate in the Al-Cu metal matrix. The microstructure of the composite contained □-Al dendrites and eutectic Silicon with Al_20_3 particles separated at interdendritic regions.

Therefore, based on the finding made in this work, I recommend this work to industries and establishments where engine piston are produced and whose desire is to produce aluminum alloys with good fatigue and shear resistance.

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