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Effect of Variation of Silicon and Copper Contents in Aluminium-Silicon-Copper Alloy

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ABSTRACT: In recent years aluminium alloys are widely used in automotive industries. This is particularly due to the real need to weight saving for more reduction of fuel consumption. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. Surfaces of aluminium alloys have a brilliant luster in dry environment due to the formation of a shielding layer of aluminium oxide. Aluminium alloys of the 4xxx, 5xxx and 6xxx series, containing major elemental additives of Mg, Cu and Si, are now being used to replace steel panels if various automobile industries. Due to such reasons, these alloys were subject of several scientific studies in the past few years [1].

This project is aimed at studying the effect of varying the composition of Copper on the mechanical properties like Tensile Strength, Hardness and Corrosion Resistance in an Aluminium-Silicon-Copper alloy. Sand casting technique being the simplest one was used for the purpose of the project and testing was done on the samples for determining the resultant mechanical properties

Keywords: Al-Si-Cu Alloys, casting, tensile strength, hardness, corrosion resistance, microstructure**.**

I. INTRODUCTION

Aluminium alloys are used in advanced applications because of their combination of high strength, low density, durability, machinability, availability and relatively lower cost as compared to other competing materials. However, the properties of commercial aluminium alloys depend on the amount of elements like magnesium, copper, silicon, zinc and other alloying elements present in them. A variation in the composition of these elements has a significant impact on the mechanical properties of the resultant alloy. The properties are also influenced by the manufacturing techniques and heat treatment procedures employed [2].

In this project, an effort is made to study the effect of variation of composition of Copper in an Aluminium-Silicon-Copper alloy. The specimens were prepared using Sand Casting for different variation of copper in the Al-Si-Cu alloy in order to study the effect of copper on the mechanical properties like hardness and tensile strength of the resultant alloy having about 5% Silicon by weight. Also, with this project we are trying to observe the Corrosion Resistant properties of the Al-Si-Cu alloy with the study of the microstructure of the alloy and its chemical compositions.

II. EXPERIMENTAL METHODOLOGY

Commercially available Aluminium, Silicon and Copper were taken for the present study. Alloy having 5% Silicon by weight was prepared and composition of Copper by weight was varied. Cylindrical specimens were cast using sand mould for different compositions of alloying elements. Chemical compositions of the resultant alloys were studied using Arc Met 930 Spectrometer. Tensile testing was done using Universal Testing machine. Hardness testing was done using Brinell Hardness Testing Machine and Profile Projector. Corrosion resistance test was done using Corrosion resistance testing specimens. Microstructure test was done using specified Microscopes. The aluminium rods obtained from casting were machined on a lathe machine so as to prepare the samples for tensile testing. The specifications of the machined samples were as:

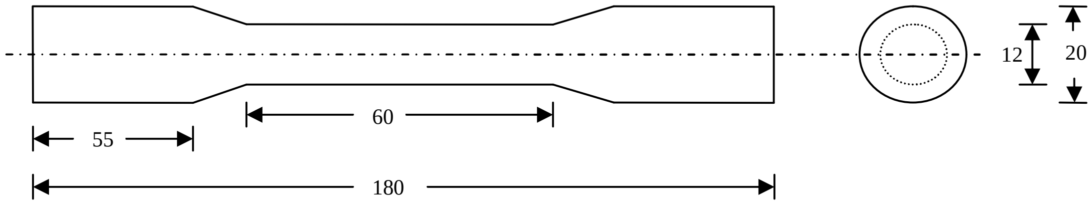

Fig.1. Tensile testing was done on a Universal Testing Machine. Brinell Hardness was measured using Brinell Hardness tester.

III. RESULTS AND DISCUSSION

A. Compositional Analysis

The following table shows the weight percentage of different elements present in the prepared specimens.

Table 1: Weight percentage of different elements present in the Al-Si-Cu specimens.

Element	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Al	96.75%	93.53%	94.70%	81.83%	86.04%	85.02%
Si	0.00%	5.59%	2.02%	8.60%	6.33%	4.15%
Cu	0.035%	0.015%	1.67%	5.82%	5.97%	9.63%
Zn	2.19%	0.54%	0.99%	2.16%	0.96%	0.72%
W	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%
Pb	0.016%	0.025%	0.21%	0.66%	0.32%	0.17%
Sn	0.00%	0.00%	0.087%	0.38%	0.10%	0.055%
Fe	0.94%	0.29%	0.25%	0.51%	0.25%	0.24%
Ni	0.00%	0.00%	0.06%	0.029%	0.015%	0.00%

The target weight percentage of Silicon in Sample 2, sample 3, sample 4, sample 5 and sample 6 was 5%. The actual percentage was 5.59%, 2.02%, 8.60%, 6.33% and 4.15% respectively which can also be considered as acceptable as it will not have a significant impact on the nature of the current study.

The target weight percentage of Copper in sample 3, sample 4, sample 5 and sample 6 was 2%, 4%, 6% and 10% respectively. However, as can be seen from the above table, the actual weight percentage was 1.67%, 5.82%, 5.97% and 9.63% respectively. As the purpose of this project is to study the effect of increasing percentage of Copper in Al-Si-Cu alloy, these values can also be taken as acceptable. It can be seen that the percentage of Copper is also varying a lot across the samples, especially in the samples which were cast later. This is a significant variation given the fact that no Copper was added during casting. However, this may be due to the Copper already present in the Aluminium taken for the study and separation of the same during melting in the furnace. As Copper being a heavier element than Aluminium, it might be possible that while melting the Aluminium alloy in the furnace, Copper particles move to the lower end of the crucible rather than being homogeneously mixed with Aluminium. Hence, in the early castings, i.e. Sample 1, Sample 2 and Sample 3, a relatively lower concentration of Copper was present whereas in the later castings, i.e. Sample 4, Sample 5 and Sample 6, a higher percentage of Copper was there. Pouring temperature, height, stirring and other factors also contributed to the resultant amount of Copper present in the Aluminium alloy.

A smaller variation in other materials was also observed in the samples which can also be attributed to separation of particles while melting and difference in densities of different metals.

B. Tensile Testing

Tensile Testing was carried out using the Universal Testing Machine. Results of tensile testing are as:

Table 2: Results of Tensile testing.

Specimen No.	Al%	Si%	Cu%	Ultimate Tensile Strength (MPa)
1	96.75	0	0.035	87.32
2	93.53	5.59	0.015	95.98
3	94.7	2.02	1.67	122.44
4	81.83	8.6	5.82	138.86
5	86.04	6.33	5.97	134.98
6	85.02	4.15	9.63	149.69

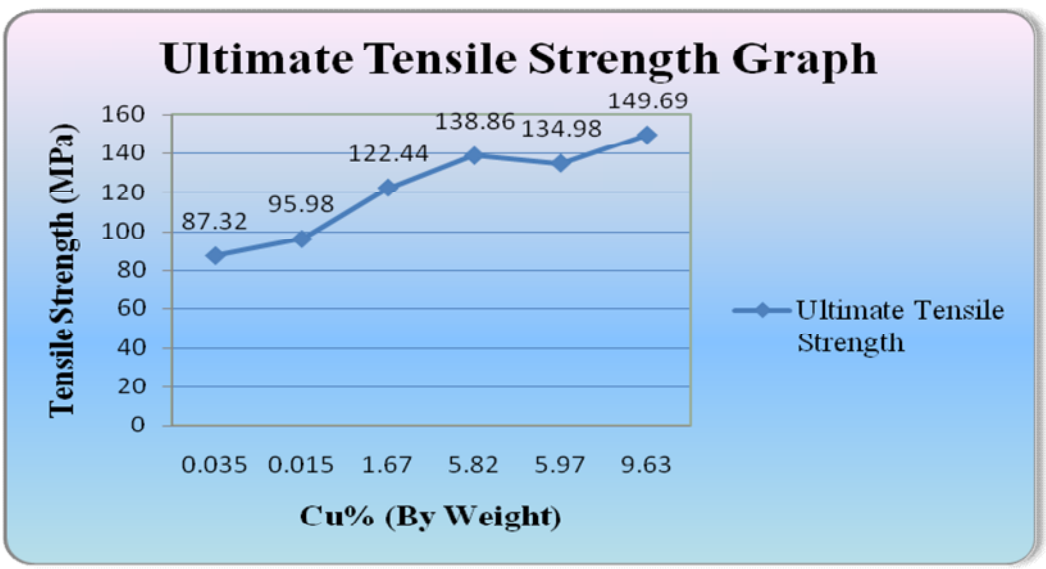

Fig. 2. Curve showing variation of UTS with Weight % of Copper.

From the above charts, it can be seen that addition of both Silicon and Copper in the Aluminium alloy increases the UTS of the resultant alloy. The UTS of sample 1 was 87.32 MPa which was pure Aluminium alloy.

As about 5% Silicon was added in sample 2, UTS increases to 95.98 MPa. With the addition of Copper in sample 3, the UTS further increases to 122.44 MPa. With the addition of Copper in sample 4, the UTS further increases to 138.86 MPa. As Copper was further increased in sample 5, the expected UTS would have been higher than that of sample 4. However, the actual UTS number was found to be 134.98 MPa. This could be due to separation of metals during melting and Copper being heavier than Aluminium, the particles of Copper moved to the bottom of the crucible. As a result, Copper content was lower in the earlier cast samples whereas there was an increase in Copper content in samples which were case later. As we see in sample 5, the UTS number is lower at 134.98 MPa.

In sample 5, as Copper was further increased along-with a decrease in the Silicon content, UTS increases. In sample 6, the addition of Copper further increased the UTS.

C. Hardness Testing

The macro-hardness testing was carried out using Brinell Hardness testing machine. Results of hardness testing are as under:

Table 3: Results of Hardness testing.

Specimen No.	Al%	Si%	Cu%	Hardness (HB)
1	96.75	0	0.035	43
2	93.53	5.59	0.015	48
3	94.7	2.02	1.67	55
4	81.83	8.6	5.82	89
5	86.04	6.33	5.97	95
6	85.02	4.15	9.63	113

The below figures show the variation of Brinell Hardness Number with variation of Copper in the Aluminium-Silicon-Copper alloys.

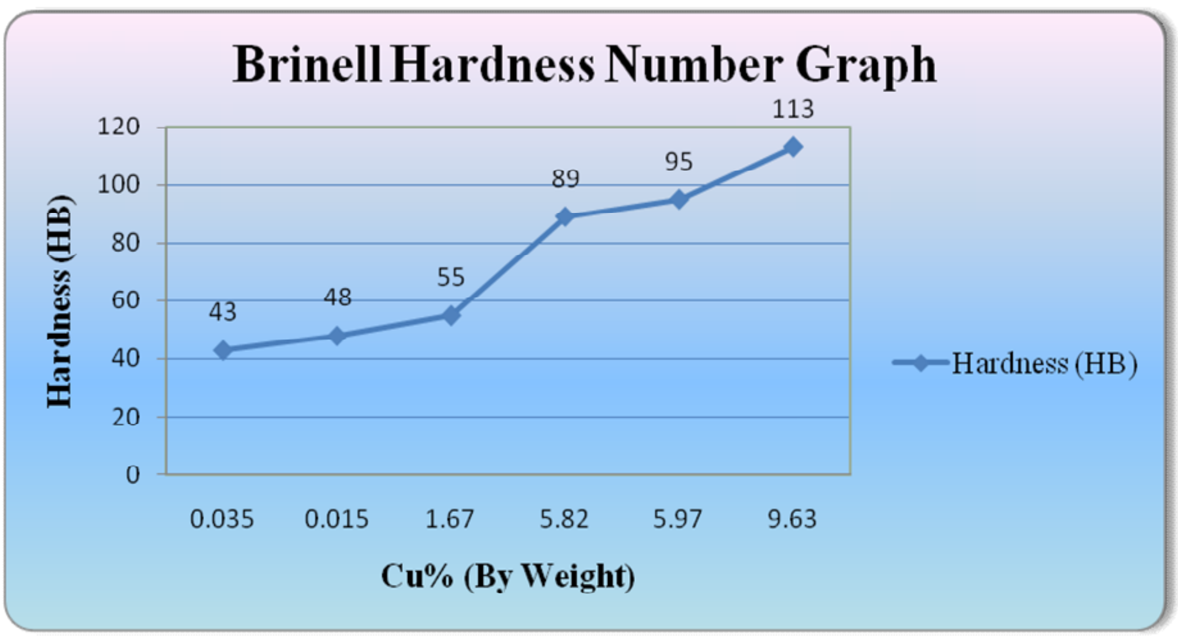

Fig. 3. Curve showing Variation of Hardness with Copper content.

As can be seen from the above diagrams, the hardness of the alloy increases when Silicon was added to the alloy. With addition of Copper in the Al-Si-Cu alloy (in sample 3), there was a minor increase in the hardness, as the difference was also minor. However, in sample 4, hardness of the resultant alloy increases drastically, as there was significant difference in the content of Copper. Again we observe slight variation in the Brinell Hardness Number with further addition of Copper. This may be due to the increased amount of Copper present in the alloy. However, in sample 6 wherein Copper content was highest, hardness increases from the previous sample.

D. Corrosion Resistance Testing

Corrosion Resistance testing was carried out under certain environmental circumstances. The sample was kept under several chemicals so as to practically notify the corrosion traces. Several readings had been taken that are shown below.

Table 4 : Results of Corrosion Resistance testing.

Sample	Cu % (BY WEIGHT)	Time	Initial	Final	Loss (%)
1	0.04%	After 24 Hrs	11.9	11.9	0.00%
		After 48 Hrs	11.9	11.9	0.00%
2	0.02%	After 24 Hrs	13.36	13.36	0.00%
		After 48 Hrs	13.36	13.36	0.00%
3	1.67%	After 24 Hrs	12.08	12.08	0.00%
		After 48 Hrs	12.08	12.08	0.00%
4	5.82%	After 24 Hrs	15.87	15.87	0.00%
		After 48 Hrs	15.87	15.87	0.00%
5	5.97%	After 24 Hrs	14.28	14.28	0.00%
		After 48 Hrs	14.28	14.28	0.00%
6	9.63%	After 24 Hrs	12.69	12.69	0.00%
		After 48 Hrs	12.69	12.69	0.00%
HENCE- NO CORROSION WAS FOUND IN THE SPAN OF 48 HOURS					
SAMPLES PASSES CORROSION TESTS					

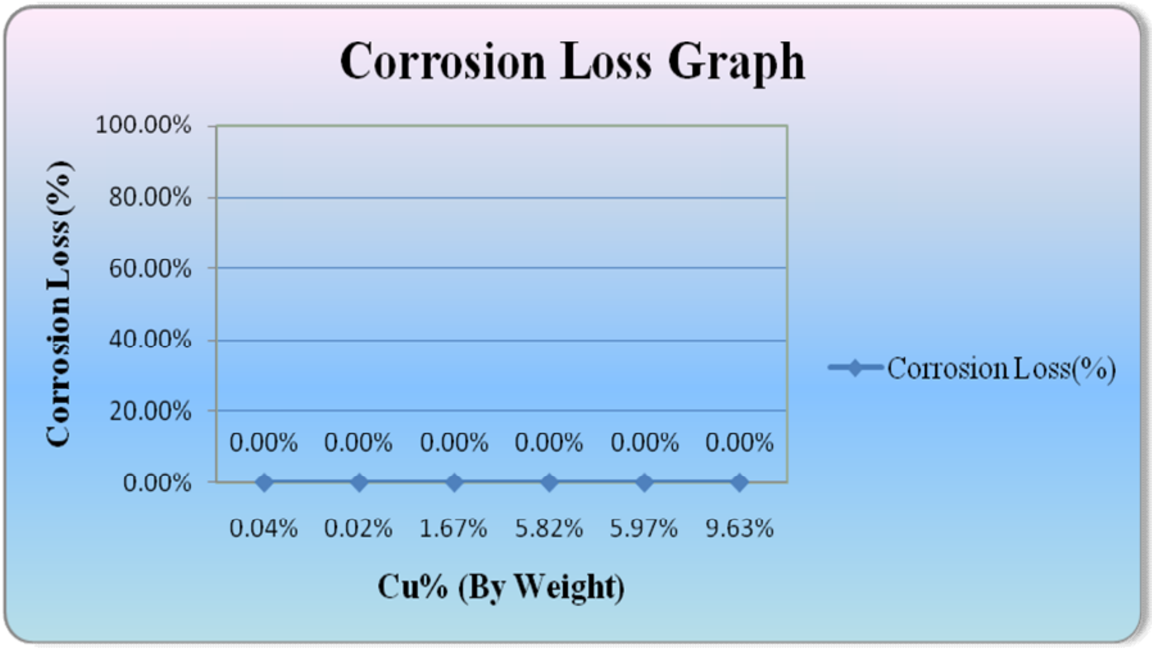

Fig. 4. Curve showing No Corrosion Loss with increase in Copper content.

From the above diagrams we conclude that there was no corrosion loss identified in the Al-Si-Cu alloy within the span of 48 hours. Thus, increasing content of copper have no impact on the corrosive properties of the alloy.

E. Microstructure

Microstructure obtained from computerized optical microscope are shown in fig.5- fig. 10

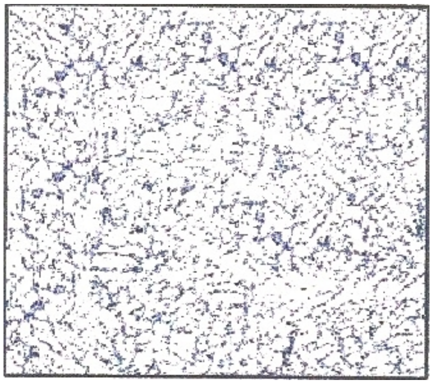

Fig. 5. Microstructure of Al.

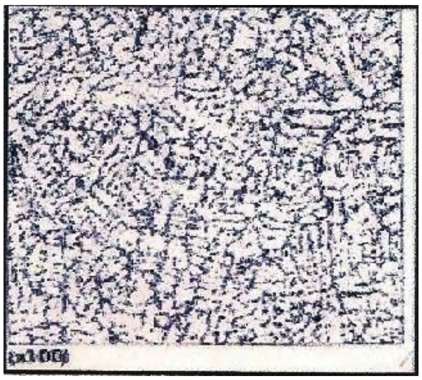

Fig. 6. Microstructure of Al-5.59Si.

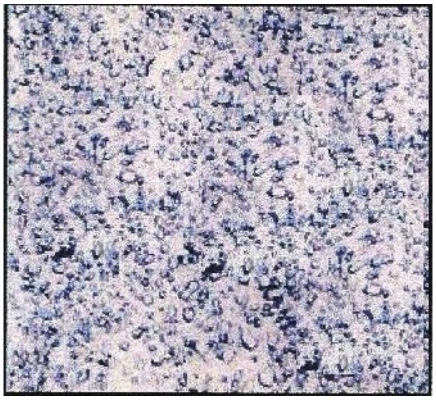

Fig. 7. Microstructure of Al-2.02Si-1.67Cu.

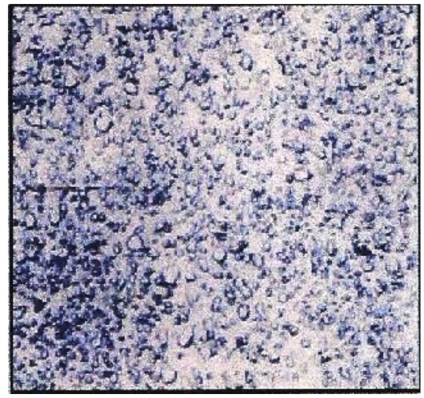

Fig. 8. Microstructure of Al-8.6Si-5.82Cu.

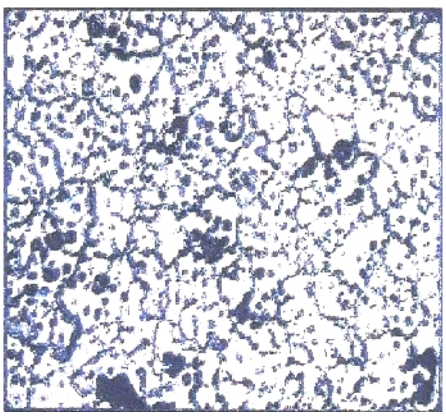

Fig. 9. Microstructure of Al-6.33Si-5.97Cu.

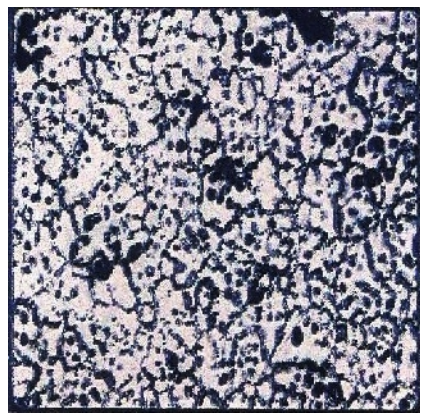

Fig. 10. Microstructure of Al-4.15Si-9.63Cu.

Figure 5 shows an optical micrograph of pure Aluminium alloy and it may be seen that more or less rounded particles of aluminium (light area, alpha- solid solution) are crystallized. The Microstructure of Al-5.59Si alloy in Fig. 6 shows comprised of a fine network of fine eutectic particles dispersed in a aluminium matrix., which are surrounded by fine eutectic silicon (dark areas). Here. silicon has networked structure. The Microstructure of Al-2.02Si-1.67Cu alloy in Fig. 7 shows the refinement of the eutectic silicon and copper particles. The Microstructure of Al-8.6Si-5.82Cu alloy in Fig. 8 shows reveals fine particles of copper, zinc mixed with eutectic particles in a aluminium matrix, the refinement of the eutectic more silicon and more copper particles. The degree of refinement of the eutectic silicon increased as the silicon content of the alloy increased beyond the eutectic composition. The Microstructure of Al-6.33Si-5.97Cu alloy in Fig. 9 shows the refinement of the eutectic less silicon and more copper particles. The Microstructure of Al-4.15Si-9.63Cu alloy in Fig. 10 shows reveals fine and high particles of copper, mixed with eutectic particles in a aluminium matrix. The degree of refinement of the eutectic copper more increased as the compared of silicon content.

CONCLUSION

The conclusions drawn from the current investigations are as under:

(i) The prepared Aluminium-Silicon-Copper alloy will have homogeneous distribution of silicon but heterogeneous distribution of copper content throughout the casting.

(ii) The amount of primary copper increases with the increase in copper amount in the casting.

(iii) Ultimate Tensile Strength increases with the increase of weight percentage of copper.
(iv) Hardness increases with the increase of weight percentage of copper.
(v) When some amount of silicon is added to the alloy, the corrosion resistant property gets enhanced.
(vi) With an increase in silicon content, there was a slight decrease in hardness.
(vii) Mechanical properties of Aluminium alloys depend not only on the content of alloying elements, but also on their relative chemistries with each other.
(viii) The Future scope and enhancement drawn from the current investigations are as under:
(ix) Pure aluminium is soft and brittle, but can be strengthened by alloying with small amounts of copper, silicon, zinc, or magnesium.
(x) The hardness of alloy is increase with increasing the copper contents.
(xi) Magnesium also has a positive impact on the tensile strength of the alloy.
(xii) The tensile strength of the resultant alloys increased with the addition of Zinc.
(xiii) By adding magnesium in al-si-cu alloy the damping can be improved. However, a number of other elements are also added in small quantities for enhanced properties.

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