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Variation of Hardness in Combined Refined and Modified Al-20Si-5Cu Alloy from Pure Aluminium

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Abstract **: This paper tries to investigate the variations in the hardness value of Al-20Si-5Cu from pure aluminium under different conditions like after refining aluminium and subjecting the Al-20Si-5Cu alloy to modification by , Phosphorous and Strontium, and from that of pure aluminium. The changes in microstructure after refinement and modification especially of morphology in primary silicon and distribution of eutectic silicon and Al_2Cu are discussed as the factors influencing hardness.**

Key words: Hypereutectic alloy solution, Grain refining, Modifier, Chemical composition, Hardness

I INTRODUCTION

Aluminium alloys have found their wide applications in transportation, military and civil aviation industry traditionally [1].Some group of alloys have found their applications in computers, architectural structures and communication systems. Aluminium combined with silicon as major alloying element offers excellent fluidity, corrosion resistance, good machinability and weldability characteristics. Copper addition to Al-Si alloy system improves tensile strength, machinability and thermal conductivity at the cost of reduction in ductility and corrosion resistance[3]. Hardness is one of the important properties of a metal which is to be characterized during material selection.

II LITERATURE REVIEW

Hardness of a material plays an important role while studying machining and tribiological behavior of it. It was observed that increase in Si content leads to increase in hardness [1,5]. Silicon is present in hypereutectic alloys in two forms (i) primary silicon, in shapes like, stars and acicular flakes in the coarse form and eutectic silicon as a compound with aluminium in inter dendritic spaces distribution and phases in which they are present play a very important role in mechanical properties including hardness[2,3] . The common grain refiners used to refine aluminium are master alloys of Al-T or Al with titan and boron in the proportion of 0.002% -0.03% respectively [1,3,4,5]. Refining of aluminium has no profound effect on hardness [5], but modification of silicon which is normally carried out by either salts of Na,P,Sr etc., or master alloys with aluminum[5]. It is also important not only the silicon content which will influence the hardness but in the hypereutectic region the morphology and topography and distribution of primary silicon also influences it [1,5]. R.Saravanan et.al during their study of effect of silicon content on surface treated Al-Si alloy found as Si content increases hardness also increases. According to Masatsuga Kamiya et al., during their machinability test, they observed the following facts which are due to hardness of material, (i) chip breakability of Al-Si binary castings is optimal between 12 – 15 % of silicon content, (ii) surface roughness is poor initially at 2- 5% of silicon content, optimal at 12% dicreases as silicon content increases and (iii) all forms of tool wear increase with increase in silicon content beyond 15% because of coarse grains of primary silicon present in the mixture. Increasing in copper content in Al-Si based alloys along with increase in strength there will be an increase in hardness[3]. The strength as well as hardness increases with decrease in purity of aluminium with other alloys[6]. H.Kaya et al., during their investigation of effect of temper gradient, growth rate and interflake spaceing on the micro hardness of directionally solidified Al-Si alloy, found that in constant temperature gradient castings growth rate increases micro hardness for a constant growth rate and an increase in interflake spacing decreases hardness. N.A.Ameer et al., during their study on effect of grain refinement and modification on dry sliding wear behavior found that hardness of modified and refined casting is higher than unmodified and unrefined casting which can be attributed to reduced average primary silicon size and modification of eutectic silicon in needle form into fine fibrous form. Combined effect of grain refinement and modification as found in hardness of a refined and modified Al-12Si 4.5cu, compared to as unmodified cast materials is higher because of modification of Si

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morphology and refinement of α-Al[12]. Mohammed et al., in their study of influence of additives found composition alone will not influence the mechanical properties such as tensile and wear or hardness, the morphology also plays an important role.

III EXPERIMENTAL PROCEDURE

Various alloys listed in Table 1. were prepared by melting commercially pure aluminum (99.7%) in clay graphite crucible in a pit type resistance furnace under a cover flux (45%NaCl + 45% KCl + 10%NaF) and the melt was held at 720ºC(for 15wt% Silicon alloys and 780ºC for 20wt% Silicon alloys), refiner Al-3B&M51,Modifiers Phosphorous and Strontium , and other required master alloys are added according to the schedule shown in Table 2 . The molds are preheated to 300ºC before pouring the molten metal for uniform cooling of melt. After casting specimens for hardness with 25 mm each thick are cut from the cylindrical block of 150 mm length. Later each specimen is polished with 60 grit on a polishing machine with 120 rpm followed by hand polishing with 200 grit, 600 grit and finally with 800 grit sand papers on a flat surface. After polishing the surface is cleaned with cotton waste to avoid any greasy surface and dust, before it is loaded in hardness testing machine. Before actual testing the machine is checked for errors (calibration) with standard specimen supplied by manufacturer of machine. Proper indenter, load and scale is selected (1/16’’steel ball indenter, 100 kg load and Rockwell B scale) in the Rockwell hardness testing machine. For proper indentation (margins from the edge and distance between indentation) a circular gird with 5mm radius offset circles is prepared, with reference to that indentation point is located suitably at 5 points on the surface as shown in the Figure 1. The results are tabulated in Table 3 and represented in the graph Fig 3 .The microstructure of all the samples is shown in Fig2.

Table 1 Chemical composition of samples a) Planned b) Actual

a)

Sample No	Composition
Sample 14	(Al+20Si)
Sample 15	(Al+20Si+0.06P)
Sample 16	(Al+20Si+0.06P+0.06Sr)
Sample 17	(Al+20Si+5Cu)
Sample 18	(Al+20Si+5Cu+0.06P)
Sample 19	(Al+20Si+5Cu+0.06P+0.06Sr)
Sample 20	(Al+20Si+5Cu+0.06P+ Al-3B)
Sample 21	(Al+20Si+5Cu+ 0.06P+ 0.06Sr+ Al-3B)
Sample 22	(Al+20Si+5Cu+ 0.06P+M51)
Sample 23	(Al+20Si+5Cu+0.06P+0.06Sr+M51)

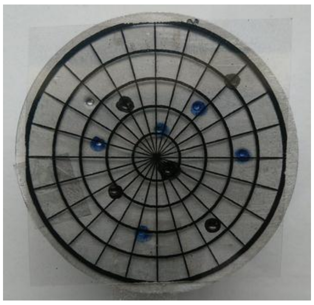
b)

Sample No	Si	Cu	Al
Sample 14	24.61	0.06	≈95.5
Sample 15	21.54	0.006	,,
Sample 16	18.65	0.006	,,
Sample 17	15.22	5.603	,,
Sample 18	22.87	4.75	,,
Sample 19	16.78	5.88	,,
Sample 20	17.53	5.6	,,
Sample 21	18.05	5.55	,,
Sample 22	20.99	4.41	,,
Sample 23	18.94	5.39	,,

Table 2 Melting Schedule for casting the required alloys

Schedule	Melt composition	Addition	Pouring Temperature	Remarks
Melt 14	(Al+50Si)	Silicon	780º C	20wt%,Remains in all the following melts
Melt 15	(Al+50Si+0.06P)	Phosphorous	---	Refiner, 0.06wt%
Melt 16	(Al+50Si+0.06P+0.06Sr)	Phosphorous &Strontium	---	Refiners, 0.06wt%
Melt 17	(Al+50Si+30Cu)	Copper	---	5 wt%,Remains in all the following melts
Melt 18	(Al+50Si+30Cu+0.06P)	Phosphorous	---	Modifier,0.06wt%
Melt 19	(Al+50Si+30Cu+0.06P+0.06Sr)	Phosphorous &Strontium	---	Modifiers,0.06wt%,0.06wt%
Melt 20	(Al+50Si+30Cu+0.06P+ Al-3B)	Phosphorous& Al-3B	---	Modifier,0.06wt%,Refiner,1wt%
Melt 21	(Al+50Si+30Cu+ 0.06P+ 0.06Sr+ Al-3B)	Phosphorous , Strontium &Al-3B	---	Modifiers,0.06wt%,0.06wt%,Refiner,1wt%
Melt 22	(Al+50Si+30Cu+ 0.06P+M51)	Phosphorous &M51	---	Modifier,0.06wt%,Refiner,1wt%
Melt 23	(Al+50Si+30Cu+0.06P+0.06Sr+M51)	Phosphorous ,Strontium&M51	---	Modifiers,0.06wt%,0.06wt%,Refiner,1wt%

a) Before indentation with Grid



b) with indentation (Blue indents are for BHN and Black for Rockwell B scale.)

Fig 1 Circular grid placed over the specimen to maintain approate distance between indentation

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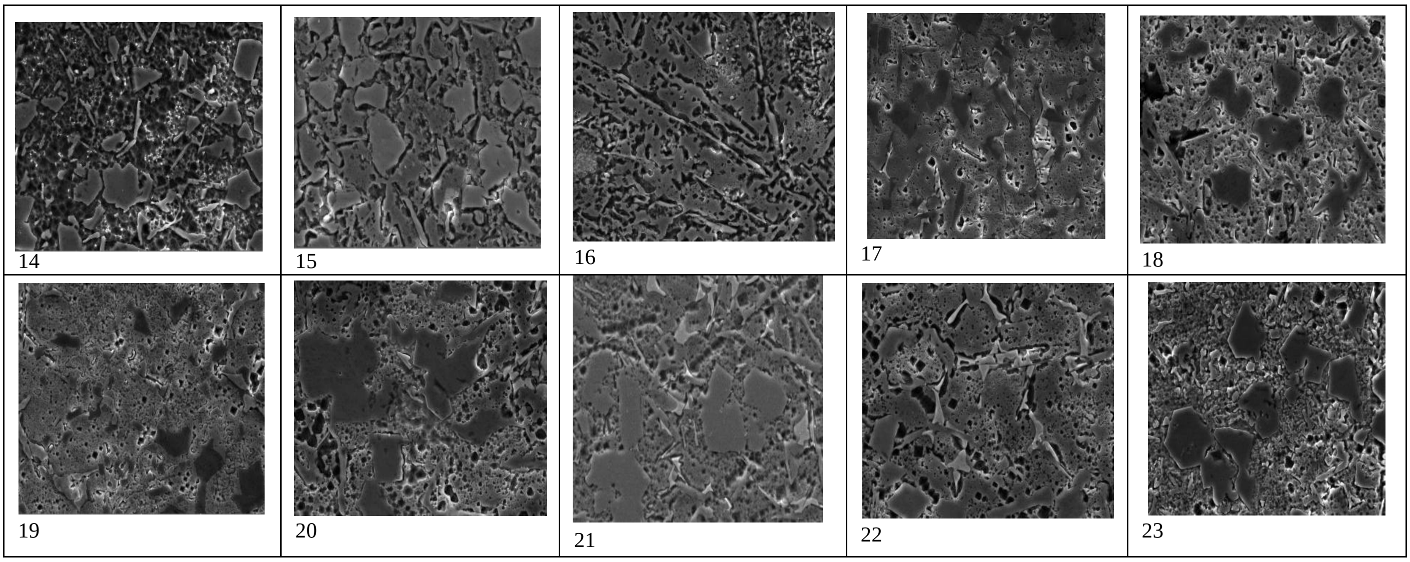

Fig 2 SEM images of microstructure of samples 14 - 23 (x1000)

Table 3 Hardness values tabulated.

Sample ID	Composition of alloy	Load(kg)		Readings					Avg of Readings	H R_B Value (Rounded)
		Minor	Major	1	2	3	4	5		
1	Pure Aluminium	10	100	50	47	44	49	51	48.2	48
14	(Al+20Si)	10	100	78	87	88	81	81	83	83
15	(Al+20Si+0.06P)	10	100	91	89	92	92	91	91	91
16	(Al+20Si+0.06P+0.06Sr)	10	100	70	82	83	87	83	81	81
17	(Al+20Si+5Cu)	10	100	42	52	54	58	51	51.4	51
18	(Al+20Si+5Cu+0.06P)	10	100	59	58	55	58	57	57.4	57
19	(Al+20Si+5Cu+0.06P+0.06Sr)	10	100	44	48	43	40	47	44.4	44
20	(Al+20Si+5Cu+0.06P+ Al-3B)	10	100	52	54	51	52	54	52.6	53
21	(Al+20Si+5Cu+ 0.06P+ 0.06Sr+ Al-3B)	10	100	41	38	48	56	50	46.6	47
22	(Al+20Si+5Cu+ 0.06P+M51)	10	100	54	58	49	46	46	50.6	51
23	(Al+20Si+5Cu+0.06P+0.06Sr+M51)	10	100	41	54	34	52	45	45.2	45

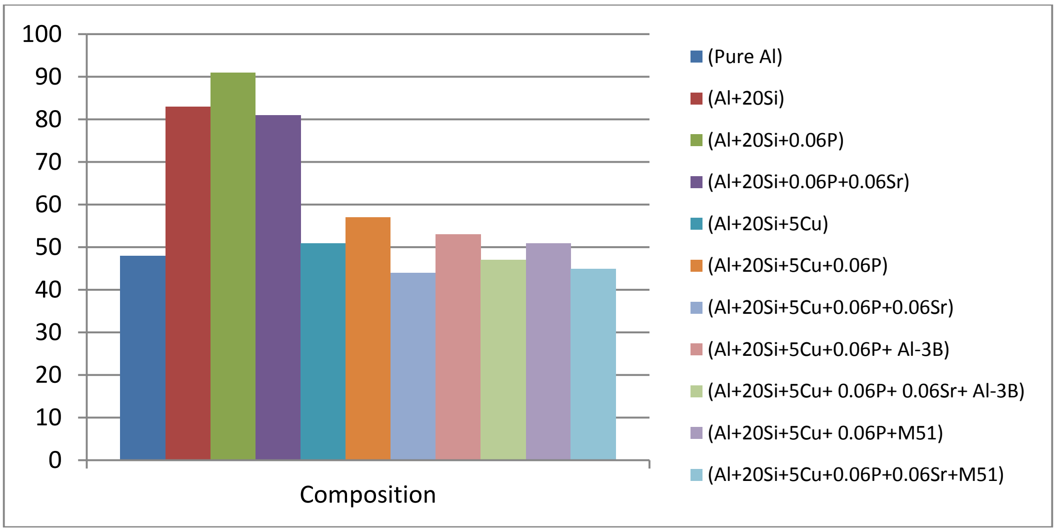

Fig 3 Graph of hardness against each composition

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IV RESULTS AND DISCUSSIONS:

In sample 1 which is pure aluminium has primary aluminium with 99.7% purity. As the Silicon is added to the solution, obviously hardness increased to the extent of 35%. This phenomenon can be attributed to coarse star and flake like structure of primary silicon which is evident in microstructure of sample 14. Further when the alloy solution is modified with Phosphorus alone hardness is increases marginally as there is no significant change in the morphology evident in microstructure of sample 15. This phenomenon of increase in hardness slightly, when modified with phosphorous as well as refined with Al-3B and 5T-1B, is observed at the later stages also after addition of copper because of the same reason which can be seen in micrographs of 18, 20 and 22. Addition of one more modifier, i e, strontium brings the hardness to the normal level and marginally lesser than the Al-20Si alloy as the primary silicon particle have been modified (from micrograph of16). With Copper addition to the mix hardness is further reduced by 37%. But as compared to unmodified Al-20Si-5Cu hardness of modified casting is slightly increased which indicates complete change in morphology of coarse Si particles to finer took place evident from micrograph of sample 19.

V CONCLUSION:

Refining of pure aluminium with Al-3B and 5T1B has no significant effect on hardness except the grain refinement. The addition of Si increases hardness. The copper addition reduces the hardness in the expected lines, which will be reduced further upon modification with Phosphorous and Strontium because of change in morphology.

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