Investigation of Optimum Addition of Phosphorous for the Refinement of Primary Silicon in Hypereutectic Al-20 Si and its Effects on Microstructure and Mechanical Properties

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Abstract--- *Hyper eutectic Al-Si alloys have been widely investigated because of their excellent properties which include excellent wear and corrosion resistance, high temperature strength, low coefficient of thermal expansion and high specific strength. The mechanical properties of hyper eutectic Al-Si alloys are mainly determined by size and morphology of primary silicon phase. In the present study refinement of primary silicon in Al-20Si alloy is carried out with the addition of phosphorous (0.01%-0.15%) and is studied using image analyzer. Refinement of primary silicon is due to reaction of the phosphorous with liquid aluminum to form aluminum phosphade, AIP, which has crystal structure very similar to that of silicon and acts as an a heterogeneous nucleant. The results clearly show that phosphorous could effectively refine primary silicon of hyper eutectic Al-20Si alloy. Addition of 0.1%P results in achieving optimum microstructure, but the addition of excess P is unfavorable to the refinement of primary silicon. The alloy with the additions of 0.1%P show improvement in mechanical properties and there is a decrease in hardness at optimum addition which means as hardness decreases strength and plasticity increases and hence wear resistance increases. The improvement of mechanical properties should attribute to primary silicon refinement.*

Keywords--- *Refinement, Image Analyzer, Hyper Eutectic Al-Si Alloys, Wear Resistance*

I. INTRODUCTION

HYPEREUTECTIC AI-Si alloys have been widely investigated because of their excellent properties, which Include excellent wear and corrosion resistance, high temperature strength, low coefficient of thermal expansion, good cast performance, and high specific strength. Therefore, the hypereutectic A1-Si alloys are widely used in aeronautic, astronautic, and automobile industries. It has been documented extensively that the microstructure of hypereutectic Al-Si alloys, prepared by conventional casting routines, usually consist of a coarse primary silicon phase in a fibrous eutectic matrix. The brittleness of coarse Si crystals (both eutectic and primary silicon) is the main reason responsible for the poor properties of Al-Si alloys because coarse silicon crystals leads to premature crack initiation and fracture in tension. In order to refine the primary silicon, many methods have been carried into execution, such as high-pressure casting, rapid solidification technique, and melt overheating treatment. In the present study the P complex modification of hypereutectic AI-20% alloys was conducted. The influences of P, on the microstructure and mechanical properties of hypereutectic Al-20% alloy were investigated.

II. EXPERIMENTAL

Al-20Si is prepared via foundry technique. Calculated quantities of commercial Purity aluminium (99.7Wt%purity) and A1-20 Wt% Si master alloy are melted in a Resistance furnace under a cover flux (45% NaCl +45% KCL + l0% NaF). The melt is held at 720˚C ± 50˚C. After degassing the melt with solid hexacloroethane(C2Cl6) , CuP chips duly packed in the aluminium foil are added to the melt for grain refinement . The melt is stirred for 30 seconds with zircon coated iron rod , after the addition of grain

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refiner. After which no further stirring will be carried out. Melts are poured after holding for about 5 minutes into cylindrical graphite mould (25 mm dia and 100 mm height) surrounded by fire clay brick with its top open for pouring. The so prepared samples are taken for macro analysis and micro analysis using image analyzer for characterization for the measurement of primary Si particles sizes . With this optimum addition of phosphorous to the melt is noted and will be used for further research work .

2.1 Process

A1P and Si are both diamond cubic with very similar lattice parameters 0.542 nm for silicon, 0.545 nm for Alp. When P is added into the melt of hypereutectic A1-Si alloys, the reaction Al+P-AlP takes place in the modification. AlP can act as the inhomogeneous nucleus of primary silicon particles in the solidification of hypereutectic A1-Si alloys, which results in the refinement of the primary silicon particles.

III. RESULTS AND DISCUSSIONS

Fig 1 shows the microstructures of Al-20Si alloy with and without the additions of Phosphorus. It can be seen that the alloy without the addition of phosphorous contains coarse, plate like, non uniformly distributed primary silicon which is the main cause for poor mechanical properties. However after the optimum addition of 0.1% P (ref Fig 2) to the melt the primary silicon becomes fine, blocky and well dispersed. But however it is clear from image analysis that the addition of excess P is unfavorable to the refinement of primary silicon.

Table 1: shows hardness of the Al-20Si alloy at different% of additions of Phosphorous

Specimens	Vickers Hardness	Specimens	Vickers Hardness
As cast	78	0.09P	32
0.01P	72	0.10P	21
0.02P	69	0.11P	36
0.03P	68	0.12P	39
0.04P	63	0.13P	59
0.05P	62	0.14P	68
0.06P	63	0.15P	69
0.07P	54		
0.08P	38		

From table 1 it s very much clear that with the optimum addition of P to the melt, hardness of the specimen decreases. which means as hardness decreases strength and plasticity increases and hence wear resistance increases.

3.1 Micro Analysis

Specimen	Perimeter	Images	Specimen	Perimeter	Images
As cast	0. 9815		0.03P	0.8770	
0.01P	0.9556		0.04P	0.8680	
0.02P	0.9539		0.05P	0.8356	

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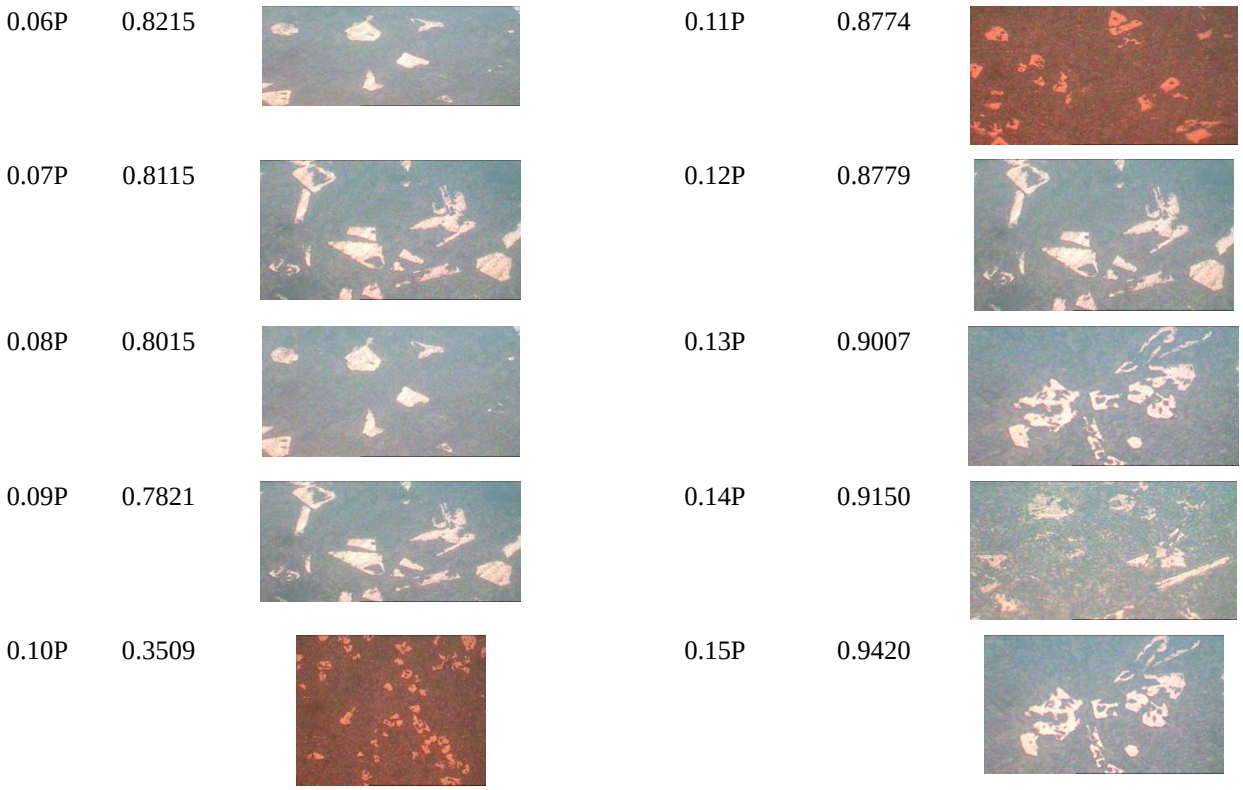

Fig .1 Primary Silicon Morphologies of Al-20Si Alloys Refined with Phosphorous

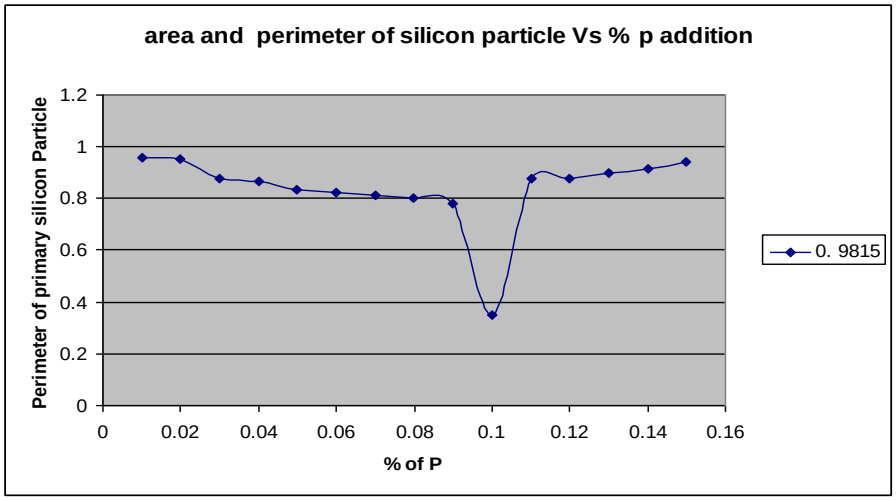

Figure 2: Area and Perimeter of Primary Silicon Vs % of P Addition

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3.2 Wear Study

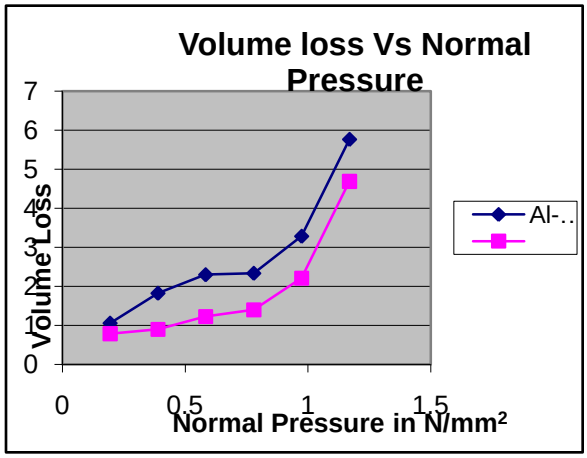

Figure 3: Volume loss Vs Normal Pressure

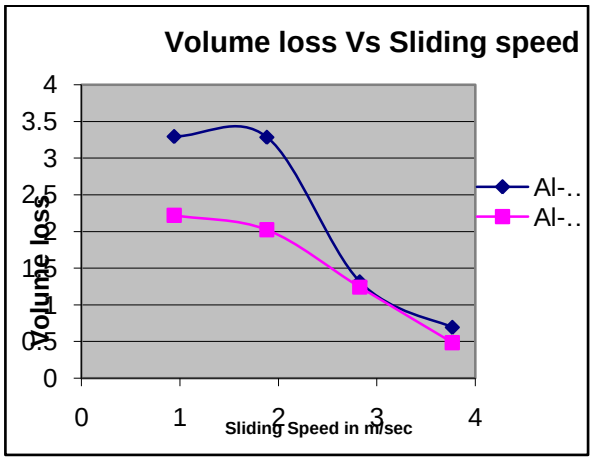

Figure 4: Volume loss Vs Sliding Speed

Wear study has been conducted for Al-20 Si alloy with 0.10%P addition and without addition of P. From the graph it is clear that Wear rate in terms of volume loss is less for the alloy with optimum addition of phosphorous for the both the tests carried out for varying normal pressure and varying sliding speed as compared to as cast alloy.

IV. CONCLUSIONS

1. Hyper eutectic Al-20Si alloy can be well refined by addition of P. The size of the primary silicon decreases with increasing P addition however it is very much clear that 0.1%P results in achieving optimum microstructure, but the addition of excess P is unfavorable to the refinement of primary silicon.
2. The mechanical properties of Al-Si are obviously improved with the addition of P. When the alloy is refined with P addition optimal combinations of strength and plasticity is obtained. The hardness of the specimen is decreases in turn wear resistance of the specimen increases with optimum addition of Phosphorous.

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