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MODIFICATION PERFORMANCE OF THE Cu-P MASTER ALLOY ON COMMERCIAL HYPEREUTECTIC Al-24Si-Cu-Mg ALLOY

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ABSTRACT
In the present study, Cu-14P master alloy has been used to modify a commercial grade Al-24Si-Cu-Mg/ LM-29 alloy. The influences of P content on the microstructure and mechanical properties of alloys were investigated. The P addition make the coarse polyhedral primary silicon particles obviously refined and the large needle eutectic silicon modified to the fine fibrous ones. The alloys with the additions of 0.4 %(Cu-14P) has the optimal microstructure and the highest mechanical properties compared with the unmodified alloy. The primary silicon of alloys can be refined from 51.88 µm to 21.53 µm. The ultimate tensile strength is improved from 174 MPa to 211 MPa. The elongation is improved from 0.94% to 1.56%. The hardness is improved from 138 VHN to 160 VHN.

Keywords: Hypereutectic Al-Si alloy, Primary silicon, Modification, microstructure, mechanical properties.

I. INTRODUCTION
Hypereutectic Al-Si alloys have been extensively used because of their properties which include excellent wear and corrosion resistance, high temperature strength, low coefficient of thermal expansion, good cast performance and high specific strength. Therefore these are widely used in aeronautic, astronautic and automobile industries [1-2]. It has been noticed comprehensively that the microstructure of hypereutectic Al-Si alloys prepared by conventional casting practices usually consist of a uneven primary silicon phase in a fibrous eutectic matrix of aluminium [3, 4].
In order to refine the uneven primary silicon many methods have been put into execution such as high pressure casting, rapid solidification technique and melt overheating treatment [5, 6]. However, these processes are complex and difficult to control. The desired properties cannot be obtained or may even become worse. The microstructure control using minor element addition is the most popular method due to its ease and effectiveness. Phosphorous is the most effective refinement element of primary silicon in hypereutectic Al-Si alloys. The size of primary silicon can be refined to 20-30 µm by adding minor Phosphor [7, 8].It is noticed that there are two modification mechanisms; one is heterogeneous nucleation and refining of primary Si phase by Al-P particles and the other is P atoms modify the morphologies of Si phases [9, 10].
The mechanical properties of hypereutectic Al-Si alloys are affected by primary Si features such as particle size, shape, volume fraction and Si content. The presence of large Si cuboids in conventionally cast hypereutectic Al-Si alloys give rise to poor mechanical and wear properties. 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 lead to premature crack initiation and fracture in tension [11]. It is well known that adding of small amounts of Cu, Mg or Ni strengthen Al-Si alloys and also the presence of Si provides good casting properties. Addition of copper to Al-Si alloys results in the formation of $CuAl_2$ phases and other intermetallic compounds, which increase strength of cast parts [12]. In the present study, modification performance of the Cu-14P for commercial LM-29 (Al-24Si-Cu-Mg) alloy microstructure and mechanical properties was investigated.

II. MATERIALS AND METHODS
CommercialLM-29 (Al-24Si-Cu-Mg) alloy was melted in a resistance heating furnace using a graphite crucible to a temperature of 720°Cunder a cover flux (45%NaCl+45%KCl+10%NaF).After degassing with solid hexachloroethane (C_2Cl_6), Cu-14%P master alloy chips packed in an aluminium foil added to the melt. The melt was stirred for 30seconds with zirconia coated iron rod after the addition of master alloy. Melts prepared with addition of calculated amount of master alloy poured into split type cylindrical graphite moulds to prepare specimens for tensile, hardness and microstructure after minutes of holding time.The details of amount of Cu-14P master alloy added to the base alloy (LM-29) is given in Table 1. The chemical composition of commercial LM-29 alloy and Master alloy was assessed using atomic absorption spectrometer (Model; Varian AA-240,

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Netherlands) and is shown in Table 2. The specimens were characterised using optical microscope, scanning electron microscope (SEM), X-ray diffractometer (XRD), Micro Vickers hardness tester and Universal testing Machine. Specimens of size Ø20x10 mm were prepared from the base alloy and standard routines.
A 0.5%HF water solution was used as an etchant for the polished samples. The specimens were examined under Carl Zeiss optical metallurgical microscope for primary silicon size and scanning electron microscope (SEM) for their microstructures. The tensile specimens of size Ø9x45mm were selected. The tensile tests were carried out using UNITEK-9450 FIE make universal testing machine. The size of the specimen for hardness test was Ø20x10 mm and hardness tests were conducted using micro Vickers hardness tester (Make: Matsuzawa, Japan, Model:MMTX7) under 1.0 kg load for a dwell time of 10 seconds. The hardness value of each alloy specimen was taken from an average of three readings.

Table 1. Chemical composition of as LM-29 and Master Alloys.

Alloy	Composition (Wt. %)				
	Si	Cu	Mg	P	Al
LM-29	24.0	1.0	1.0	-	Bal
Cu-14P	-	85.67	-	14.33	-

Table 2. Compositions of the alloys used for microstructure and mechanical properties studied.

Alloy Code	**Alloy Composition (wt. %)**	**Addition level of P (wt. %)**	**Addition level of Cu (wt. %)**
B1	LM-29	-	-
B2	LM-29+0.2%(Cu-14P)	0.02	0.2
B3	LM-29+0.3%(Cu-14P)	0.04	0.3
B4	LM-29+0.4%(Cu-14P)	0.06	0.4

III. RESULTS AND DISCUSSION

Figure 1 a-d show SEM photomicrographs of LM-29 alloy before and after the addition of the master alloy. The microstructures of all the alloys consist of primary and eutectic Silicon dispersed in the aluminium matrix. It can be observed in Figure (a) that the distribution of primary silicon is not uniform compared to that in Figure (b), (c) and (d). The primary silicon size in the alloy B1 ranges from 32 µm to 77 µm and that in B4, it ranges from 15 µm to 38 µm. So the size of the primary silicon particles was observed minimum in the B4 alloys. This could be due to the formation of Al-P and Cu_3P particles upon reaction of Cu-P alloy with liquid aluminium. The Al-P and Cu_3P particles act as heterogeneous nucleating sites for silicon particle during solidification of hypereutectic Al-Si alloys [8]. Figure 2 depicts the X-Ray diffraction pattern of the master alloy employed here for modification of commercial LM-29 alloy. The peaks of XRD show the presence of major phases like Cu_3P which confirms the constituent phases. The Cu_3P particles act as heterogeneous nucleating site for the silicon particles during solidification and hence modification effect.Figure 3 depicts the variation of the average size of primary Si in the modified and unmodified LM-29 alloys.The primary Si size has been reduced from a maximum of 52 µm in the unmodified alloy (B1) to 22 µm in modified alloy (B4) which is about 43% reduction in primary silicon size.
Figure 4 a-c show the mechanical properties; ultimate tensile strength (UTS), % elongation and hardness respectively. It is clear that there is a improvement in UTS, % elongation and hardness due to modification effect. The modified alloy containing 0.4%wt.of Cu-14P shows the maximum improvement in mechanical properties compared to alloys induced with lower addition level and base alloy. The values of UTS, % elongation and hardness in B4 alloy are 212 MPa, 1.56% and 160 VHN respectively and these in base alloy B1

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are 175 MPa, 0.94% and 138 VHN respectively. This improvement in mechanical properties evidences that the addition of copper to the Al-Si-Mg alloys improves its mechanical properties especially ductility. Addition of Cu leads to the formation of Al_2Cu phases and other intermetallic compounds which influences the strength and ductility [5].

IV. CONCLUSIONS

- The hypereutectic Al-24Si-Cu-Mg alloy can be well modified by minor addition of Cu-P and the average size of primary silicon particles reaches 22 µm in B4 alloy. The primary silicon without modification is coarse, polyhedral and unevenly distributed. After modification, the primary silicon is fine, cuboid and well dispersed in the aluminium matrix.
- The mechanical properties of hypereutectic Al-24Si-Cu-Mg alloys are improved noticeably with the addition of Cu-P. When the above alloy modified with 0.4 %(Cu-14P), UTS, %Elongation and hardness improved to 212 MPa, 1.56% and 160 VHN from 175 MPa, 0.94% and 138 VHN of the unmodified alloy.

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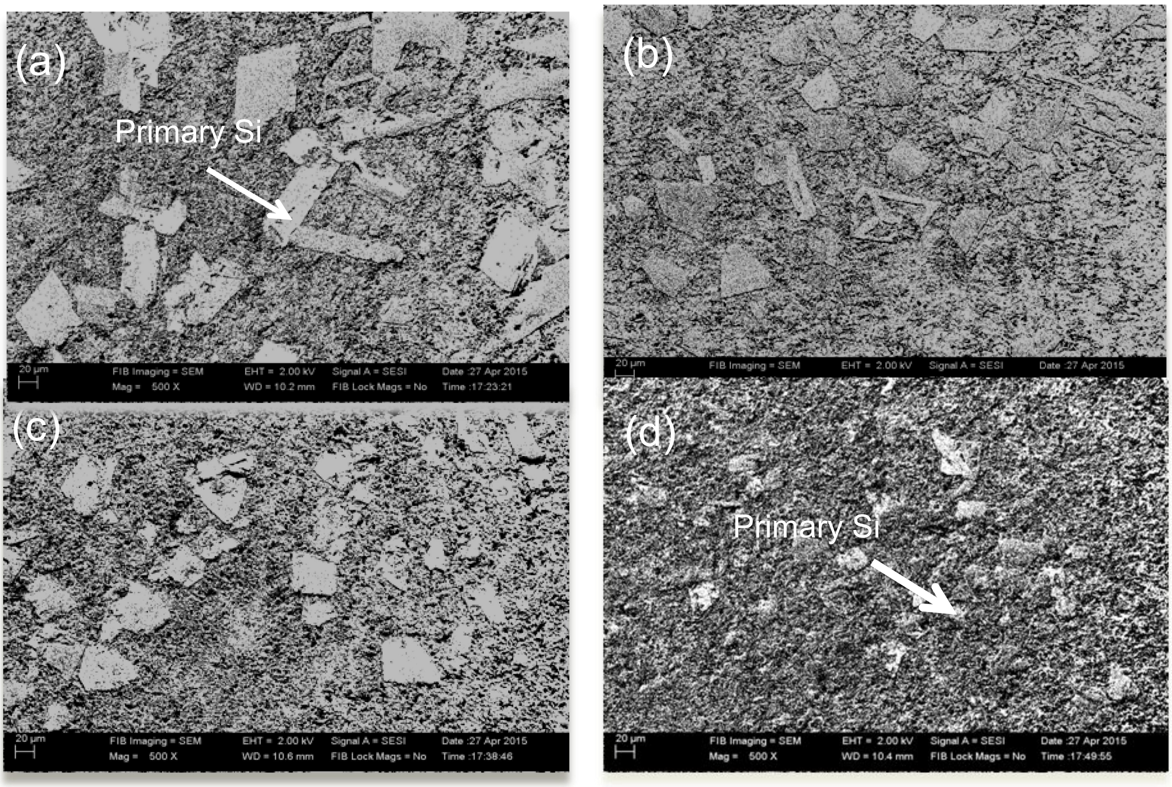

Figure 1. SEM photomicrographs of LM-29 alloy

(a) as cast alloy (b) with 0.2 %(Cu-14P) (c) with 0.3% (Cu-14P) (d) with 0.4% (Cu-14P).

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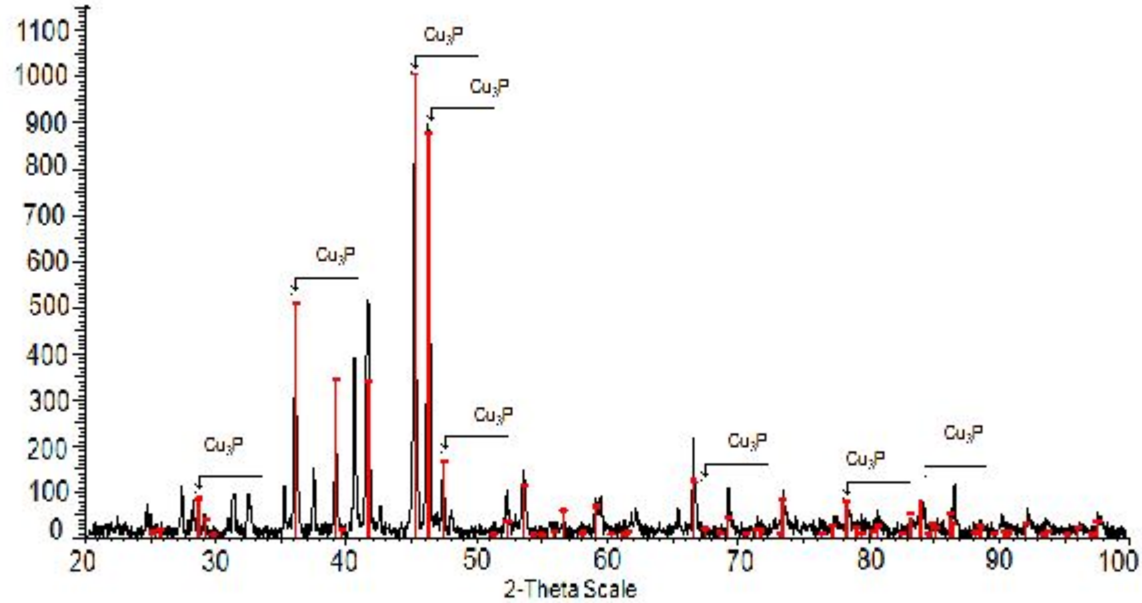

Figure 2. XRD Pattern of Cu-14P master alloy.

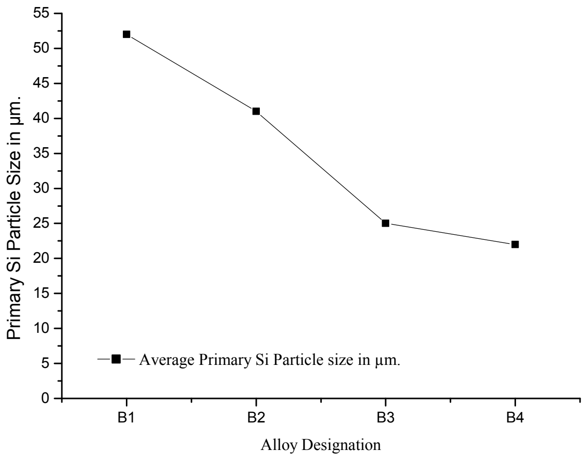

Figure 3.The variation of primary Si average size.

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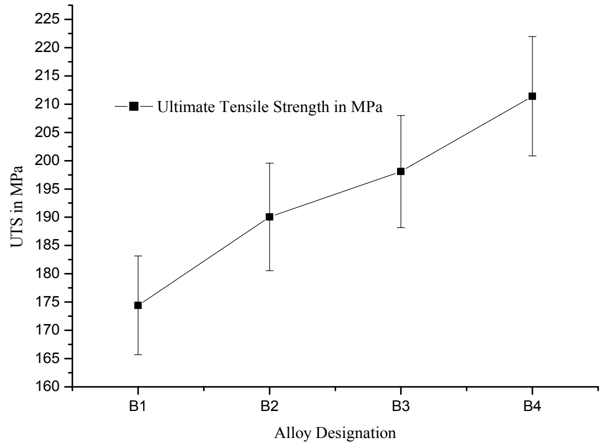
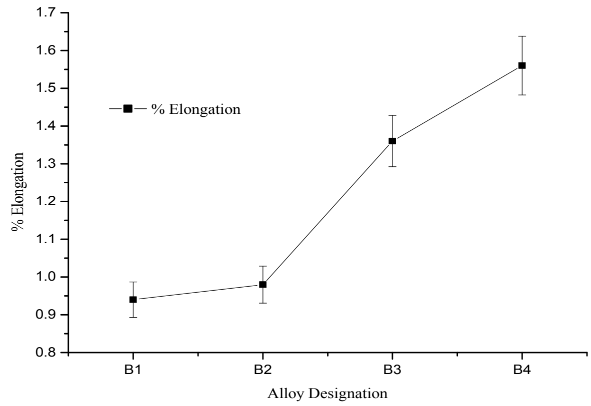
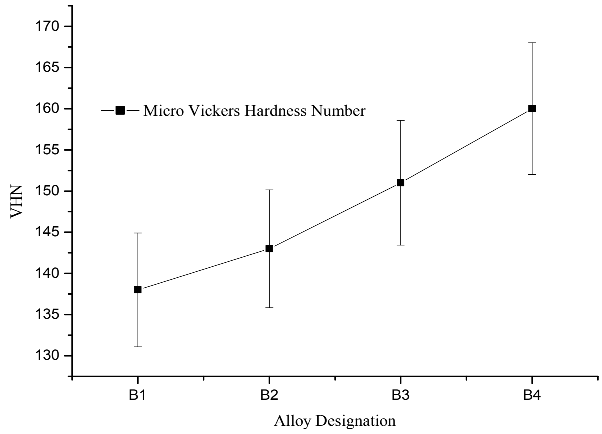


(a)



(b)



(c)

Figure 4.The mechanical properties; a) Ultimate tensile strength (UTS), b) % Elongation and c) Hardness.

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