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The Copper Influence into Physical and Mechanical Properties of the Al-5Si Alloy

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ABSTRACT

The microstructure and the hardness due to the addition of copper of the Al-Si-Zn-Mg-Cu Alloy have been investigated. The copper content varies from 0 wt.%– 5 wt.% to see how the alloy's microstructure and hardness change. The Heat treatment at temperature 510 °C for 5 hours and then cooling to ambient temperature has fostered the dissolution of copper in the crystal and then precipitate during cooling. The results show that the alloying element forms a phase distributed in the matrix of the alloy. Increasing the content of the copper makes the form of the second phase more minor, and at the matrix show, fine particles distributed mostly entire of the surface—the hardness of the alloy increase as the copper content increase. The increase in hardness might come from the fine particle dispersed in the matrix. The onset, endset, and melting temperature tend to decrease as the copper content increase.

Keywords: *Aluminum alloy, microstructure, hardness, Copper*

1. INTRODUCTION

In the automotive industry, the capability to determine heat transfer plays a vital role in engine design. The material to produce a strong wall is required to handle the impacts of non-consistent temperatures [1]. Meanwhile, mechanical stresses induced by heat transfer cause the compromising of engine components' efficiency.

Aluminum-based alloys are one of the choices as engine block raw materials to anticipate heat stress, heat transference, and heat flux, which are contrasting. The application of cast Al-5Si alloy usually as an engine block material due to its properties; lightweight, good strength, good castability, good ductility, and good corrosion resistance [2].

Solution treatment to strengthen the materials could create via nanoscale precipitation β"-Mg2Si lead [3–5]. Further strengthening can also be achieved by adding copper to this alloy [6–8]. Strengthening of the Al-Si-Mg-Cu alloy after heat treatment has been studied so much, but the Cu effect on the Alloy properties is still unclear [9–16].

The solute content in the cast alloy is higher than the solute in the wrought Al-Si-Mg-Cu alloy. The strength of the alloy due to the addition of copper increased as the content of the Cu increased [17–20].

Strengthening after heat treated-cast Cu-Al-Mg-Si alloy due to precipitation of Q′–Al5Cu2Mg8Si6, and θ′–Al2Cu were reported. It has been concluded that the strengthening due to Cu addition is still debatable [18,19,21]. Addition Cu risk reduces the ductility of the alloy [17,22]. If the ductility decrease, the hardness might be increase, and the melting temperature might be increased.

Effect addition elements in Al-Si alloy show different properties due to different intermetallic phases formed. The intermetallic phase formation strongly depends on the type and content of the element added. Hence, the intermetallic phase changed the microstructure, strength, ductility, hardness, and corrosion properties. The increasing Mg or copper content had increased the alloy strength. Nevertheless, In all cases, the ductility of the alloy is decreased. Rising iron content will reduce the strength and ductility of alloy[23].

In this study, we investigated the influence of copper on the microstructure, hardness, and melting temperature of the Alumunium base alloy.

2. METHODOLOGY

The sample alloy Al-Si-Mg were obtained from the foundry company with four different Copper content, named by C0 (0 wt.%), C1 (1,5 wt.%), C3(3 wt.%), and C4(5 wt.%). The samples were aged at three temperatures (140 °C, 180 °C, and 220 °C). Then the process continues with heat treatment, where the alloy has been heated treated at 510 °C for 5 hours and then cooled to ambient temperature.

Before the identification process, firstly, the sample goes through the polishing stage. The emery paper SiC was used to polish the samples. In an ultrasonic cleaner, the sample is rinsed with ethanol then etched to reveal the microstructure.

In this study, we carry out three types of identification: microstructure, hardness, and melting temperature. Optical Microscopes were used to observe the microstructure of the samples due to their transformation by the copper addition. The hardness was measurement by using Microhardness Vickers. The melting point was observed using a thermal gravimetry analyzer.

3. RESULTS AND DISCUSSION

3.1 Composition

Table 1 shows the result of the elemental composition of the sample alloy measured using X-ray Fluorescence. The Silicon Addition improves the alloy castability, while Zinc and Magnesium were used to improve the corrosion resistance.

It appears that the value of the elemental composition of the smelted sample has shifted from the composition design made. This condition can occur due to the infiltration of inter-phase elements through the diffusion process when the sample is heat-treated.

3.2 Microstructure

Figure 1 shows an optical microscope image that reveals the microstructure of the alloy with 400X magnification. At 0% Cu content, the sample forms a microstructure, as shown in Figure 1a. The Si-rich part forms a kind of net formation that surrounds the matrix. It also appears that at that time, the matrix had not been infiltrated by other elements.

Table 1. XRF result of alloy element.

Samples	Element (wt.%)				
	Si	Zn	Mg	Cu	Al
C0	5,0	1,0	0,41	0	balance
C1	4,9	0,9	0,39	1,5	balance
C2	4,9	1,0	0,40	2,9	Balance
C3	5,1	1,1	0,41	4,9	Balance

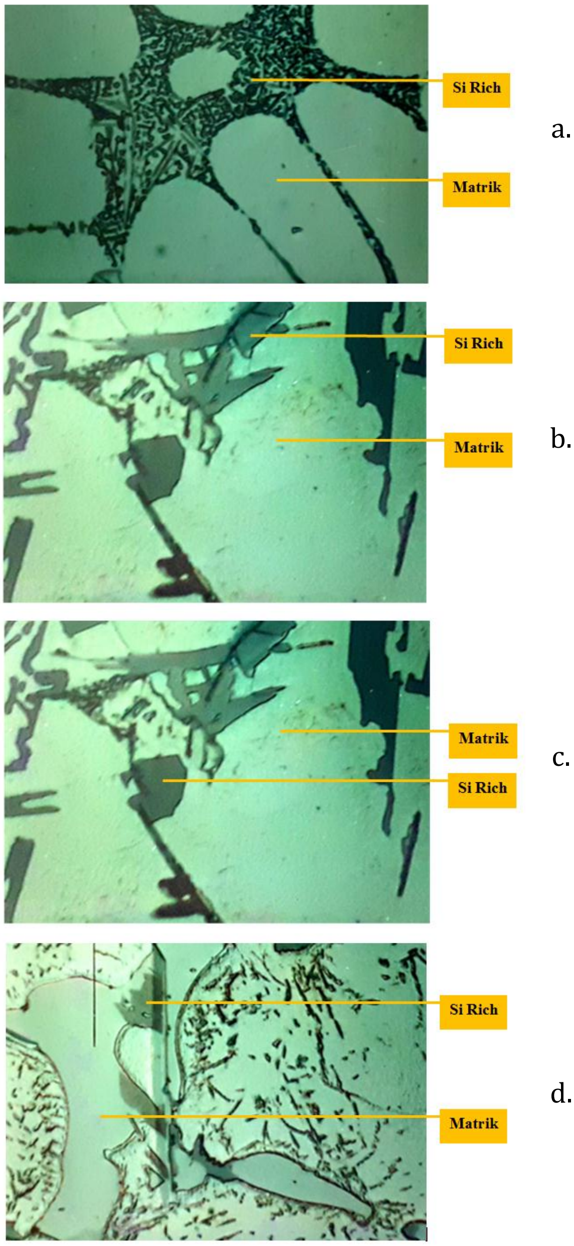

Figure 1. Microstructure of the alloy surface at 400X magnification with Cu presence a) 0 wt.%, b) 1,5 wt.%, c) 3 wt.%, d) 5 wt.%.

At 1,5% Cu content, it appears that the Si-rich part has started to grow to form grains, as shown in Figure 1b. At 3% Cu content, as shown in Figure 1c, it appears that the Si-rich grains are now dispersed to form homogeneity. At 5% Cu content, it appears that the Si-rich grains are more dispersed and appear to be diffusing with the matrix, as shown in Figure 1d [5].

3.3 Hardness

Table 2 shows the value of the hardness of the alloy that depends on the content of the copper. The addition of the copper increases the hardness of the matrix and also on the Si-rich phase. From the microstructure, the matrix shows more precipitate, which makes it harder than without copper addition.

The Si-rich phase has become more spreading in the alloy on increasing copper. It seems that increasing copper content makes the Si-rich phase smaller and spread on the matrix and hence hardens the matrix [16,17].

Table 2. The melting point of the alloy

Samples	Hardness (HV)	
	Matrix	Si rich phase
C0	72,7	83,2
C1	85,9	168,8
C2	124,7	168,8
C3	128,1	170,3

The hardness of the matrix becomes higher as the content of the Copper increase. This increase is related to the more even distribution of the Si-rich phase in the matrix. The copper adding to the alloy compound increases the dispersion of the Si-rich phase in the alloy further. The presence of this Si-rich phase makes the hardness value of the sample increase almost two times.

3.4 Melting Point

Figure 2 shows the result of the Thermal Gravimetry Analysis. This method was used to investigate the melting temperature of the alloy sample.

Table 3 shows the T_{onset}, T_{endset} and T_m. From the table, we can see that the addition of copper also strongly influences the melting temperature, even only in small values. These influences are seen in the evolution formation of the Si-rich phase due to copper addition.

Melting points T_m and T_{endset} decrease as the copper content increase. However, T_{onset} increase and then decrease. The change in T_{onset} might come from the dispersion of the Si-rich phase in the matrix.

Table 3. The melting point of the alloy

Samples	T_{onset} (°C)	T_m (°C)	T_{endset} (°C)
C0	525	580	635
C1	562	575	630
C2	540	570	625
C3	510	560	618

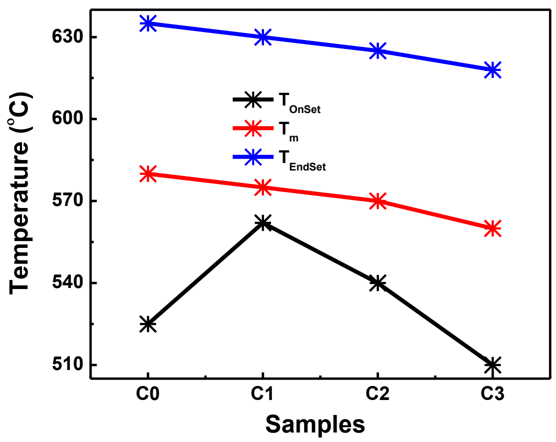

Figure 2. The melting point of the alloy.

4. CONCLUSION

Investigation on the influence of copper on the Al-Si-Zn-Mg-Cu alloy shows a strong influence on its properties, such as microstructure, hardness, and melting temperature. These strong influences come from the increment of Si-rich phase dispersion, which changes due to the copper addition in the alloy sample. This condition can occur due to the infiltration of inter-phase elements through the diffusion process when the sample is heat-treated.

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