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Structural modifications in semi solid processed LM4

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Abstract: This paper presents a report on the study of structural modifications LM4 processed by semi solid metallurgy. This was with the view to determine effects of degree of cold work, thermal treatment temperature and soaking time on the structural formations in the alloy. LM4 alloy was prepared and cast in sand mould into rods of diameter 12 mm and 200 mm in length. The cast rods were then heated to different temperatures which fall within the slurry region of the alloy. The heated samples were soaked at these temperatures for various times. There was also a set of non-treated control samples. The thermally treated rods were subjected to various degrees of cold work after which the metallographic examination of the samples was carried out. The observed microstructure of the alloy showed significant modifications.

Keywords: Semi-Solid Metallurgy, Microstructre, Slurry Zone, LM4

1. Introduction

Processing of materials within their slurry temperature range is a very trendy and emerging technology that has been identified as to possess great potential. Processing of materials within the slurry temperature is popularly referred to as semi solid metallurgy. In search for a single-step manufacturing process for components with various shapes, sound structural integrity, and properties comparable to the wrought state at a low cost similar to casting, semi-solid metallurgy may provide the solution. It offers distinct advantages over other near-net-shape manufacturing processes. In this process, cast parts are produced from slurry kept at a temperature between solidus and the liquidus isotherms. This process produces complex parts with better quality when compared to parts made by similar processes. It also allows net shape forming, reducing further machining operation. The process combines the advantages of both liquid metal casting and solid metal forging. Although semi-solid metallurgy is already a viable manufacturing method, it is still under intensive development and critical breakthrough is still expected. Current research efforts have been concentrated on the low melting alloys, particularly aluminum and magnesium alloys (Margarido and Robert, 2003; Czerwinski, 2008b, Wierzbińska and Sieniawski , 2006, Yang et al., 2008).

The influence of the semi-solid slurry on the component's integrity is complex (Czerwinski, 2008a). The common assumption that the benefits of semi-solid processing arise exclusively from the flow behavior of the partially solidified metal is, apparently, a simplification. In general, the slurry affects product integrity through a reduction in porosity and changes in the microstructure. The effects of microstructure on components integrity is well documented (Adedayo, 2010, Adedayo et al., 2010, Adedayo, 2009a, Adedayo, 2009b, Ibitoye et al., 2010).

2. Experimental Procedure

Alloy of Al-Si-Cu (LM4) was prepared by melting Al-Si master alloy, Al-Cu master alloy and Al scrap in a lift out electric crucible furnace. Four kilograms (4.5 kg) of Al-Si master alloy, 3.5 kg of Al-Cu master alloy were melted with 6 kg of aluminum scrap (See table 1). These were measured using a weighing balance, and all melted in a lift-out electric crucible furnace.

This was cast in sand mould into rods of diameter 12 mm and 200 mm in length. The quantitative chemical analysis of the cast material was carried out using Atomic Absorption Spectrophotometer (AAS). The result of the chemical analysis is presented in table 2. The cast alloy was allowed to solidify and then ejected from the mould. The cooled rods were then heated to different temperatures of 630, and 635°C which fall within the slurry region of the alloy. The heated samples were soaked at these temperatures for various times of: 5, 10, 15, and 20 min. After the samples were soaked for the required period, they were removed from the furnace and quenched in water. There was also a set of non-treated samples. These served as control specimen. The thermally treated rods were subjected to various degrees of cold work. 10 %, 15%, 20%, 30% degrees were used. The metallographic examination of the samples was also carried out from which the micro-structural modifications in the alloy were studied.

Table 1. *Proportion of materials charged for the production of LM4 alloy.*

Material	**Weight**	
	Kg	%
Al-Si	4.5	32
Al-Cu	3.5	25
Al scrap	6.0	43
Total	14	100

Table 2. *Chemical composition of the prepared alloy.*

Elements	***Average (wt%)***
Al	89.631
Si	5.8010
Cu	3.8320
Mg	0.4116
Fe	0.2320

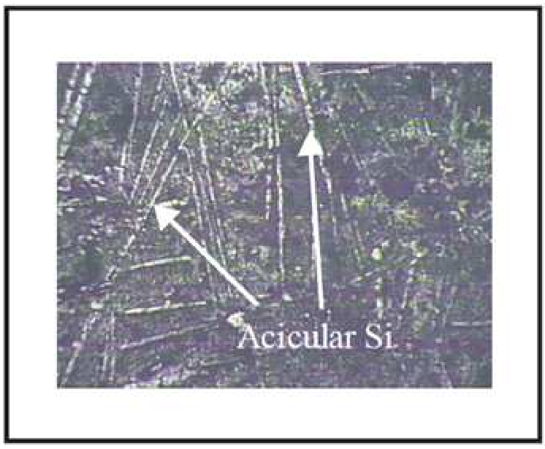

Figure 1. *Microstructure of untreated LM4 alloy*

3. Influence of Thermal Treatment on Microstructure

Figure1 shows the microstructure of the untreated LM4 alloy. The proportion of acicular silicon seen in the micrograph is high relative to microstructure of the thermally treated alloys. This may be attributed to changes in morphological characteristics of the Si phase due to thermal treatment (Liu et al, 2003). Figures 2 to 5 show the microstructures of the treated specimen. Primary aluminum phase and eutectic (Al/Si) are seen in Fig 2a. The morphology of the primary aluminum phase appears somewhat globularized. $CuAl_2$ particles are seen inside the primary aluminum phase (Fig. 2b and C), a situation which may be attributed to precipitation of the $CuAl_2$ during cooling after thermal treatment (Margarido and Robert, 2003). Figure 3a shows strained aluminum phase, which evidenced the effect of cold deformation. Figure 3b reveals that some phases are actually dissolving at this thermal treatment temperature.

In Fig. 3c, Al_5FeSi precipitate is found sandwiched in between the boundaries of the primary phase. The fractured nature of the precipitate may suggest the brittle nature of this compound. In general; the microstructures reveal various precipitates (Figures: 3d, 4b, 4c and 5d). The range of precipitates in the alloy is a bit large and consists of: $CuAl_2$, $CuAl_2Mg$, Mg_2Si, AlMnFeSi, $MgZn_2$, Al_3Ti, Mg_2Al_3, Al_5FeSi etc (Liu et al., 2003; ASM, 1990). The nature of the precipitates whether they are brittle or ductile) and their location (sandwiched between grain boundaries or entrapped in the primary/eutectic phases) will significantly affect the property of the alloy.

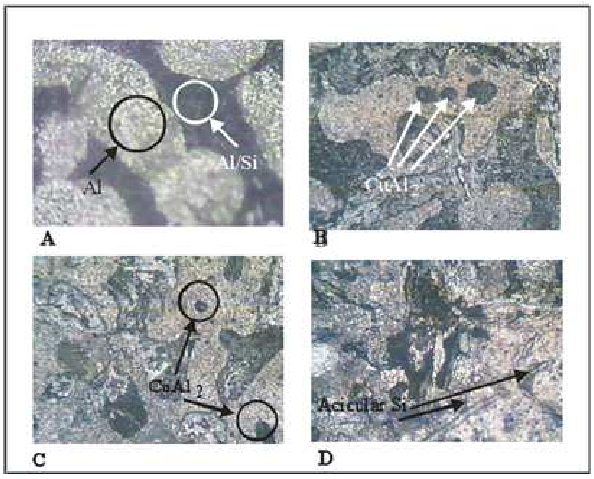

Figure 2. *Microstructure of thermally treated LM4 alloy at 635°C and 0% deformation (A) for soaking time of 15 mins. (B) 10 mins. (C) 5 mins. (C) 0 mins.*

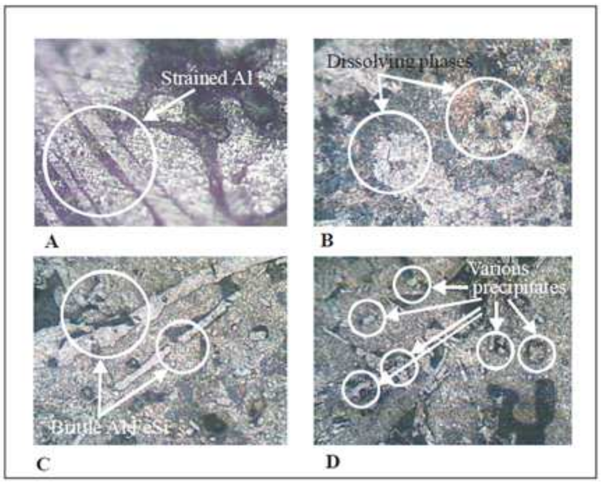

Figure 3. *Microstructure of thermally treated LM4 alloy at 635°C and 15% deformation (A) for soaking time of 15 mins. (B) 10 mins. (C) 5 mins. (C) 0 mins.*

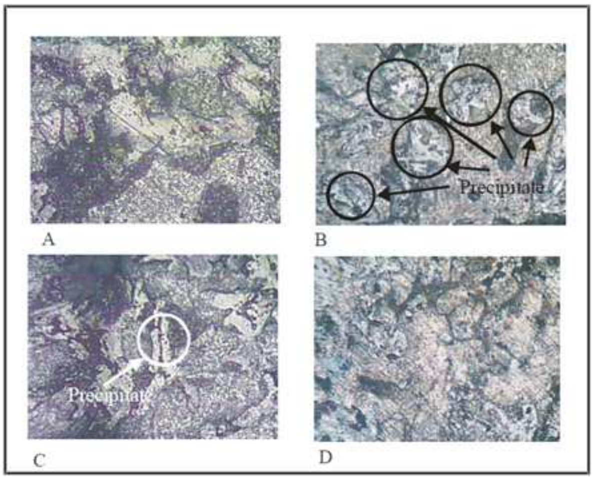

Figure 4. *Microstructure of thermally treated LM4 alloy at 635°C and 20% deformation (A) for soaking time of 15 mins. (B) 10 mins. (C) 5 mins. (D) 0 mins.*

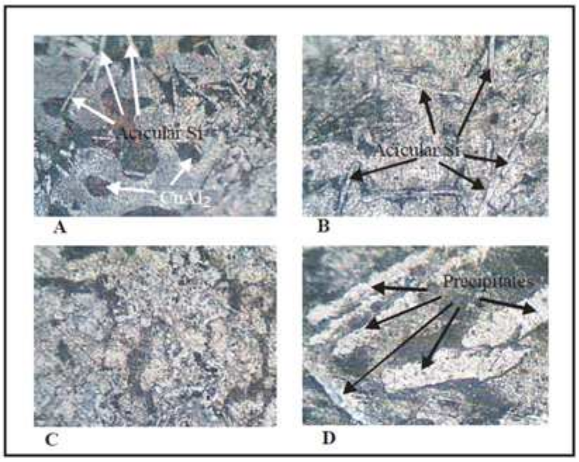

Figure 5. *Microstructure of thermally treated LM4 alloy at 630°C and 0% deformation (A) for soaking time of 15 mins. (B) 10 mins. (C) 5 mins. (C) 0 mins.*

4. Conclusion

Slurry processed Aluminum-Silicon-Copper alloy (LM4) has been produced and cold worked. The percentage of the major alloying elements in the alloy compared well with chemical composition of standard LM4 alloy. Observed microstructures show significant changes in phases present due to thermomechanical treatments within the slurry zone of the alloy.

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