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Effect of Manganese on Intermetallic layer Morphology between Dies and Al-Si alloy

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Die soldering phenomena has been a problem encounter in die casting industry. Several methods already developed to mitigate and reduce their detrimental effect. Manganese was known for their capability to suppress the harmful effect of iron rich intermetallic phase. In this work, the effect of Manganese to the intermetallic layer morphology was investigated. The experiment was carried out by immersion of H13 into molten Al-Si alloys. The alloy was added 0.1-0.7% Mn with immersion time carried out for 10 to 60 minutes. The immersion held at various holding temperature of 680-740^{o}C. The intermetallic layer was then characterized using micro hardness, scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The result showed that compact and broken intermetallic layer was formed during immersion process. Observation also showed that Manganese reduced intermetallic layer thickness without reacted with the layer. Furthermore, mechanical properties by hardness method showed no significant changes of intermetallic layer hardness value in relation to the manganese addition.

Keywords: *Die soldering, intermetallic layer, manganese, Aluminium-silicon alloy.*

Die soldering is one of the major causes of die failure and occurs directly as a result of interactions between the die steel and the injected molten aluminium alloy [1]. Numerous researches already conducted to study die soldering phenomena. Sticking of the casting alloy to the die, as a direct result of die soldering, can produce defective castings, hinder ejection of the casting from the die and shorten the useful die life [2]. Several researchers studied the effect of element on capability to reduce the detrimental effect of soldering phenomena. Xiaoxia et al. [3] studied that the existence of Si could reduce that interaction between die and molten aluminium. Nevertheless, another work by Springer et al. [4] showed different result where the addition of Si accelerate reaction layer in solid-semisolid interdiffusion.

Manganese were known as effective element for neutralize the detrimental effect of iron rich intermetallic phase, especially β-$Al_9Fe_2Si_2$ into less harmful of α-Al(MnFe)Si. Studied by Chu et al. [5] showed that the ability of molten metal to be ejected from the die will increase by at least 0.4% manganese addition. Their studied showed the Mn also increase the intermetallic layer thickness. However, different result was obtained by Shankar et al. [6,7] which observed that the addition of manganese into molten aluminium slows the growth of the intermetallic layer. Preliminary studies on Al 12%Si by Harjanto et al. [8] showed that manganese addition could reduce the formation of compact layer at about 39%.

In general, the intermetallic layer consists of compact intermetallic and broken intermetallic layer, which will be refers as compact and broken layer in this paper. The presence work aims to investigate further effect of manganese addition into Al-7%Si and Al-12%Si alloy on the intermetallic layer morphology of H13 surface with different holding time and temperature.

The materials studied in this work were master alloy of Al-7%Si and Al-12%Si which added 0.1, 0.3, 0.5 and 0.7% Mn in the melting furnace. No modifier or grain refiner was added to the alloys. Half cylinder sample of annealed H13 tool steel with 30 mm in diameter and 4 mm in height was prepared. H13 steel samples then polished to 1000 grit prior the immersion into the molten alloys. The H13 sample then dipped into molten Al-7% and Al-12%Si alloy for 10-60 minutes at holding temperature of 680-740^{o}C. The temperature of the melt was measured using a k-type

thermocouple. After the dipping process, the samples were air cooled to room temperature. The cross sections of the dipped samples were prepared for metallographic observation using Scanning electron microscopy and Energy Dispersive X-Ray Spectrometer (SEM/EDX) were used to measure and characterize the intermetallic layer.

The immersion test was conducted to investigate the relation between Manganese additions to the intermetallic layer growth at H13 contact surface. For Al-7Si, the morphology of compact layer seems influenced by the Mn content and the holding temperature. In Fig 1, the value appear shifted to higher Mn content in positive parabolic curve as the holding time increases for holding temperature of 700°C. The difference between holding time is not clearly seen at low Mn content.

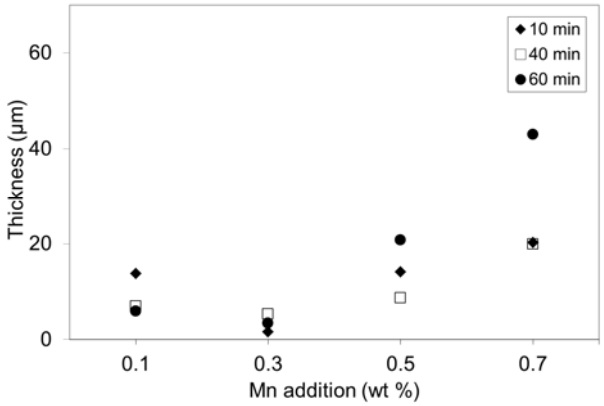

Fig. 1 Effect of Mn addition into Al-7%Si alloy at temperature 700°C on the thickness of the compact layer

For Al-12Si, as seen in Fig. 2, it shown that the Mn content and holding temperature also affected the compact layer morphology, where the compact layer morphology appeared reduced as the Mn and holding temperature increases. Generally, the compact layer has higher iron content than broken layer. EDS analysis of the layer as seen in showed the chemical composition range for binary phase and ternary phase such as $FeAl_2$, η-Fe_2Al_5 and α-$Al8Fe_2Si_2$. Analysis shows no significant effect of Mn content level to the intermetallic layer chemical composition. Furthermore, XRD analysis did not show any appearance of quarternary intermetallic phase.

Addition Mn to Al-Si alloy could reduce the thickness of the compact layer. The layer thickness also influenced by the holding temperature. The Mn seems effectively reduced the formation of compact layer without reacting with the intermetallic layer phases. Although, the phenomena in lower holding temperature for Al-7Si requires further investigation.

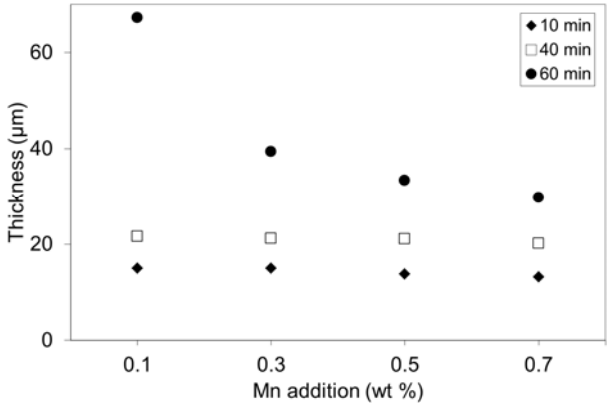

Fig. 2 Effect of Mn addition into Al-12%Si alloy at temperature 720°C on the thickness of the compact layer.

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