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Interfacial Microstructure of Sticking Phenomena between Die Casting Dies and Molten Al-Si Alloys

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The die casting die for sticking phenomena has been devised experimentally, the interface where shows sticking phenomena has been sampled by focused ion beam (FIB) method for transmission electron microscope (TEM) observation, and its microstructure has been checked to understand the mechanism of sticking phenomena. Sticking phenomena has been caused experimentally, a disc located at the center of die casting die which has sticked aluminum has been removed after casting, and then an interface between die and sticked aluminum has been formed as a thin film sample for TEM by FIB. Large dispersoids can be observed at the interface, and those were almost Al(Fe,Mn)Si-intermetallics according to EDS analysis. Changes of the number of dispersoids and their morphology has been confirmed with the difference of chemical composition in Al-Si alloys.

Keywords: *sticking phenomena, die casting, molten Al-Si alloys, FIB, TEM*

1. Introduction

The die casting method is especially suited for applications where a large quantity of small to medium sized parts are needed, ensuring precise surface quality and dimensional consistency. The die casting Al-Si alloys are very attractive for many industrial applications due to their interesting mechanical properties and light weight. The serious problem in die casting industries is the creation of sticking phenomena between the die casting dies and Al-Si alloys during casting process. This phenomena is based on the interaction between the molten material (Al) and the elements at the surface of the die when occur to form of intermetallic compounds, such as Al-(Fe,Mn) or Al-(Fe,Mn)-Si. For improving the casting process of these alloys have been proposed not only the new chemical composition of commercial Al-Si alloys but also the special surface treatments of dies.

We report on study of the microstructure in the interface between die casting die and molten Al-Si alloy using the transmission electron microscope (TEM) observation ad the aim of this investigation is better understanding of sticking phenomena mechanism.

2. Experimentals

The material under investigation were the commercial purity Al -8.5 % Si -0.2 % Mg - 0.6 % Mn - 0.2 % Fe(#1), Al - 10.4 % Si - 0.28 % Mg - 0.66 % Mn - 0.08 % Fe (#2) and Al - 2.0 % Si - 5.7 % Mg - 0.65 % Mn - 0.13 % Fe (#3) alloys developed for anti-sticking. The sticking phenomenon was investigated on three types of alloys. For FIB and TEM techniques, a representative area of the disc located at the center of the die casting die with sticked aluminum was separated. The microstructure of the interface between the die casting die and the sticked Al alloy was investigated by means of the energy dispersive X-ray spectroscopy (EDS) and TEM (200 kV Topcon EM-002B). TEM samples have been prepared using FIB milling (Hitachi FB2200).

3. Results and discussion

Figure 1 shows the top- and side- view on the cut die with sticked Al (#2) alloy (this alloy was not removed during cutting process – the cohesion between the Al and the die had to be very strong). The same area was used for TEM sample preparation and by the help of FIB milling (Fig 2) was prepared the specimen with sizes 1.5 – 2 um X 1 um and thickness less than 150 nm (according to zero loss peak analysis by EELS). Figure 3 shows TEM image of the interface between stacked Al (#2) alloy and the die. The upper area displays the region with stacked Al and the bottom the die. In the Figure 3 the dark particles and crack (white contrast between two layers) are also displayed and for better orientation in the image the particles are marked by black arrows. As you see there are no needle- or rot- shaped particles. The mean diameter of the particles is about 350 nm and the thickness between two layers dark particles is about 100 nm. In the case of this layer is the same size as the interacted zone for sticking (reported generally), this is quite smaller than those.

Figure 4 shows results of EDS analysis for area from A to B (4 a) and from C-D (4 b). These areas are clearly designated in Figure 3. In the region from A to B (this area includes the dark particles) the amount of Mn and Si elements are higher in comparison with the matrix or the die and the average ratio Mg/Si is 8:1. The similar particles were also detected in #1 alloy. In the case of investigation of alloy with designation #3 we did not observe clearly these particles and this is the reason for theory that these small particles of Al-(Mn, Fe)-Si are created at the interface between die and molten Al during die-casting and its size probably affects sticking.

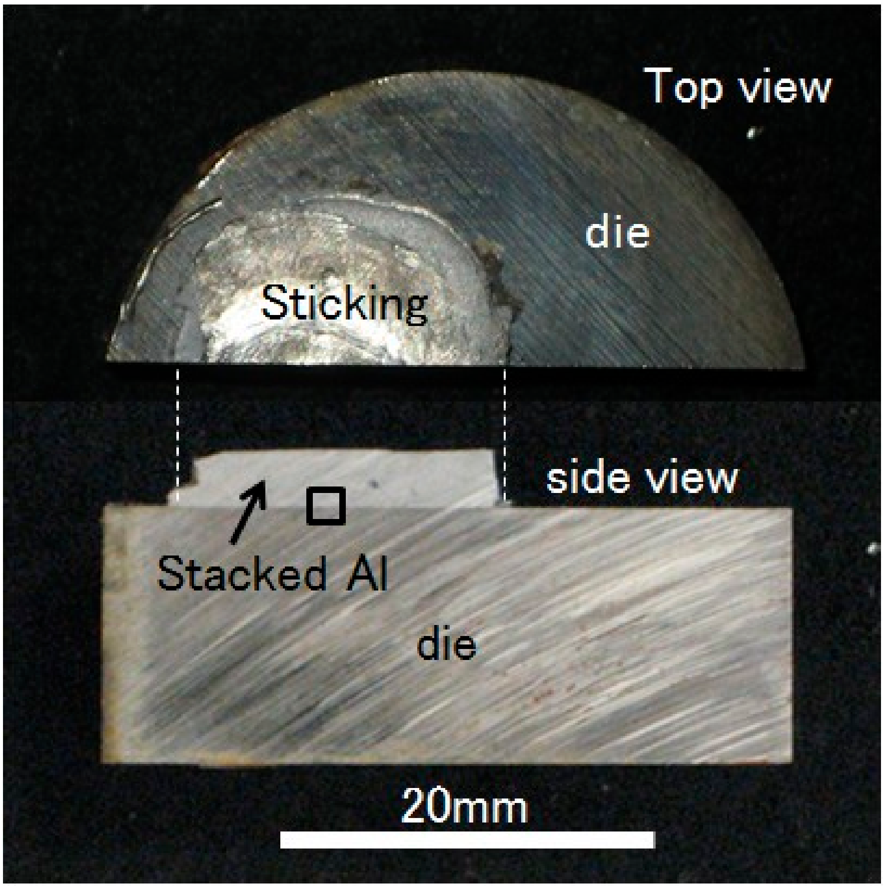

Fig. 1: Outlook of a cut die with sticking of #2 alloy.

4. Summary

The combination of FIB method and TEM was used for investigation of the sticking phenomena in Al-Si alloys.

(1) TEM samples of Al-Si alloys have been prepared using FIB milling and the microstructures of samples were investigated by the TEM.
(2) We detected the small dark particles with sizes about 350 mn in #2 alloy.
(3) These particles are consisted of Al, Mn, Fe and Si (using EDS analysis).

References

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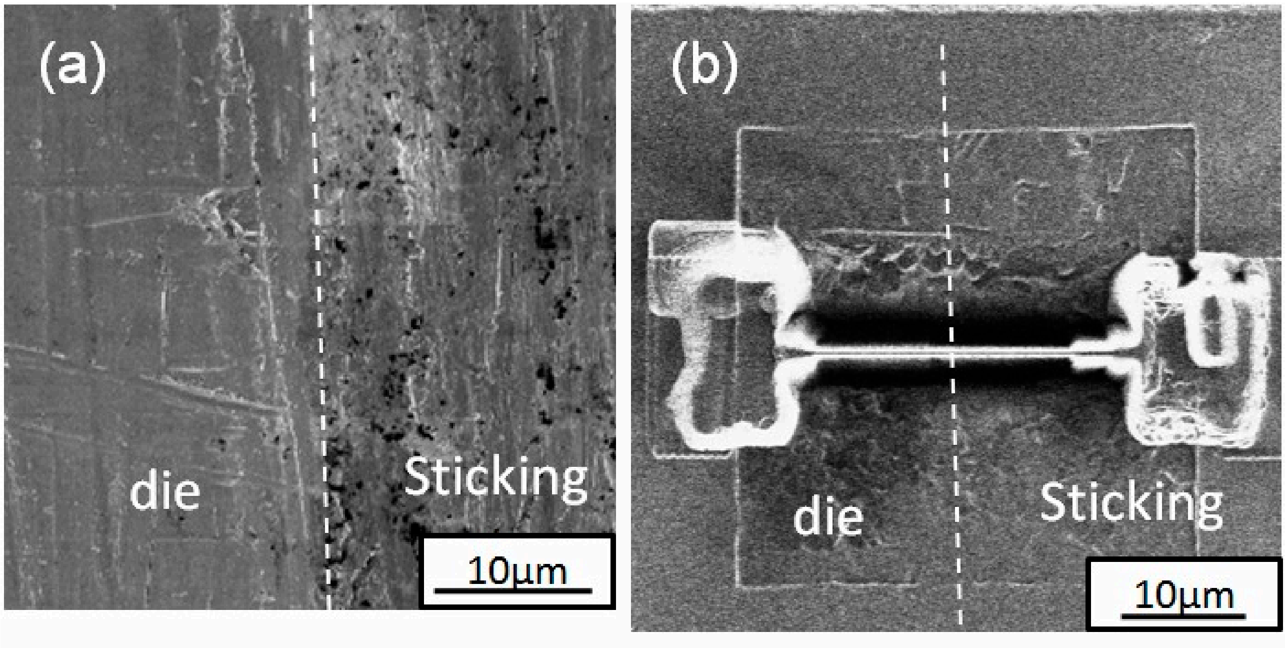

Fig. 2: (a) SEM image of the interface between stacked #2 alloy and a die and (b) secondary ion image by FIB at the same position as (a).

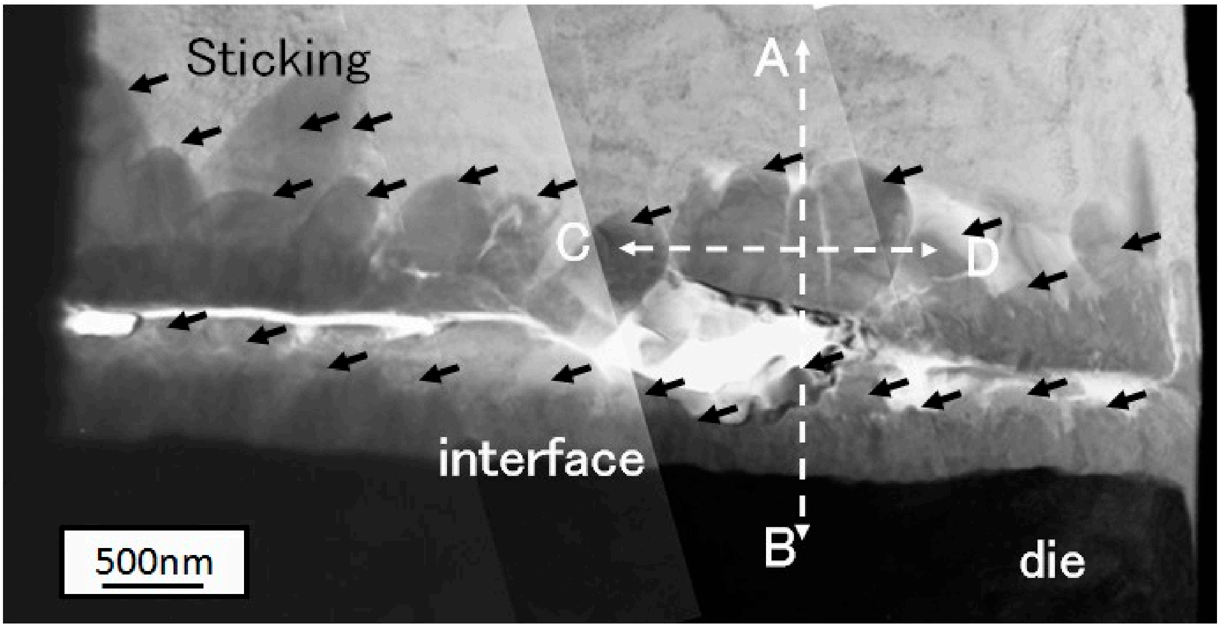

Fig. 3: TEM image of the interface between stacked #2 alloy and a die obtained for the sample prepared by FIB.

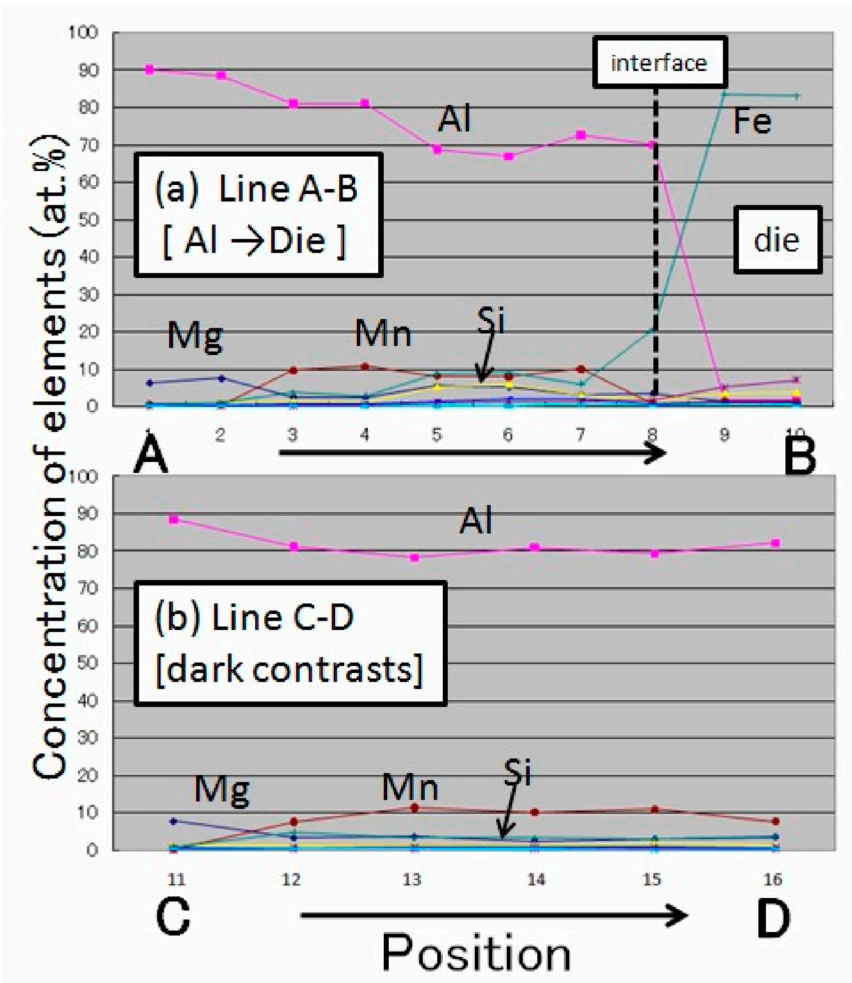

Fig. 4: Summary of EDS analysis obtained for TEM sample of #2 alloy in Fig. 3. (a) for line A-B through the interface and (b) for line C-D on the dark particles.