Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Defect susceptibility of tensile properties to microporosity variation in as-cast Al-xSi alloys

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The variability in the defect susceptibility of tensile properties to microporosity variation in as-cast Al-xSi (x=2,5,8,11) alloys was investigated in terms of the effective void area fraction which includes the fraction of micro-voids and the damage evolution of eutectic Si particles. The tensile properties of Al-xSi alloys depend fundamentally upon the microstructural change, with a remarkable deviation by microporosity variation. The defect susceptibility of UTS and elongation is practically varied with the area fraction of eutectic Si particle. Also, the contribution of effective void area fraction to the defect susceptibility was estimated by the constitutive model for tensile instability.

Keywords: Defect susceptibility, Microporosity, Al-Si alloy, Tensile property

1. Introduction

Tensile property of Al-Si castings depends practically upon the porosity variation [1-8], and the UTS and elongation are empirically described in terms of power law relation between the defect susceptibility to microporosity variation and maximum value of a defect-free condition as following equations [3-6]:

$$e = e_o [1 - f]^a \quad (1)$$
$$s = s_o [1 - f]^b \quad (2)$$

where e and s are the elongation and UTS of a material with a microporosity f, e_o and s_o are the elongation and UTS of a defect-free material, and a and b can be defined as the defect susceptibility of the elongation and UTS to microporosity variation, respectively.

2. Experiments

The Al-xSi binary alloys (x=2,5,8,11) used in the present study were fabricated with addition of 0.02%Sr, via a gravity-casting process. A melt controlled at 710 °C was poured into 5-step metallic mold (width = 120 mm, thickness = 5 ~ 25 mm, length = 50 mm per thickness) heated to approximately 200 °C.

The tension test was carried out at room temperature under strain rate of 2.78×10^{-4} s^{-1} using an extensometer. The microporosity was measured by SEM fractography analyses on the fractured surface of the entire specimen. Also, the individual size of the micro-voids and the spacing between micro-voids on the fractured surface were measured via image analysis of SEM observations.

3. Result

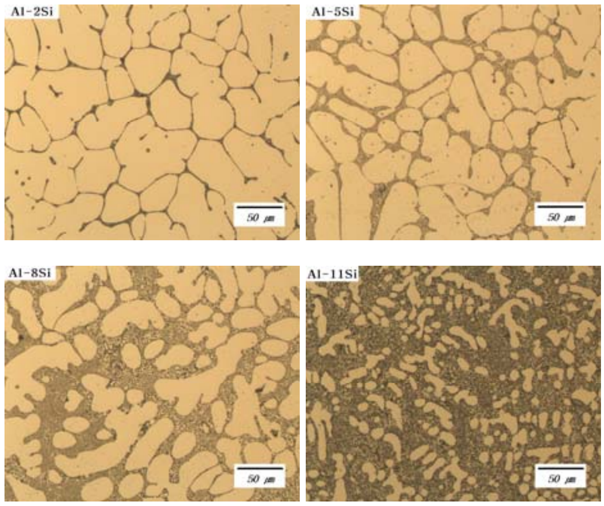

Fig. 1 Optical images of as-cast Al-xSi alloys.

Table 1 Microstructural features of Al-xSi alloys.

Microstructure \ Alloys	2Si	5Si	8Si	11Si
Grain size (μm)	675	524	427	393
Nominal fraction of Si-colony (%)	6.2	18.3	34.0	50.8
Fraction of Si-particle (%)	2.7	6.4	11.9	17.8
Width of pro-eutectic α-Al(μm)	76.9	55.9	33.4	20.7
Thick. of Si-colony (μm)	5.9	13.7	34.6	42.8

Figure 1 shows typical microstructural images of Al-xSi alloys. The area fraction of Si-particle and SDAS are remarkably varied with nominal Si-content.

Typical values of various microstructural features are listed in Table 1.

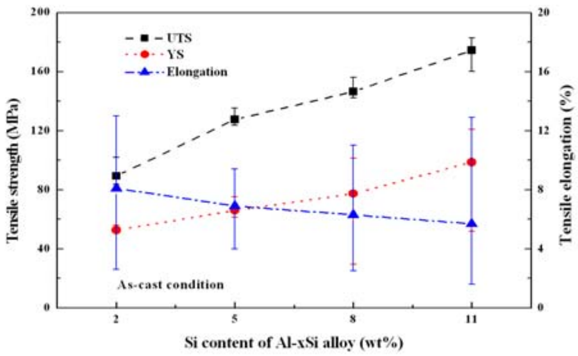

Fig. 2 Variation of tensile properties on Si-content.

Figure 2 shows the variability in the tensile properties on Si-content. The UTS and YS are remarkably increased with Si-addition, whereas the tensile elongation decreased with a considerable deviation for each alloy condition.

The overall dependence of elongation (a) and UTS (b) on microporosity variation was described via the defect susceptibility are shown in Figure 3. The nominal value of defect susceptibility increases with Si-content. And, the difference at a given microporosity is mainly arisen from the microstructural changes, i.e. the fraction of Si-particle and SDAS.

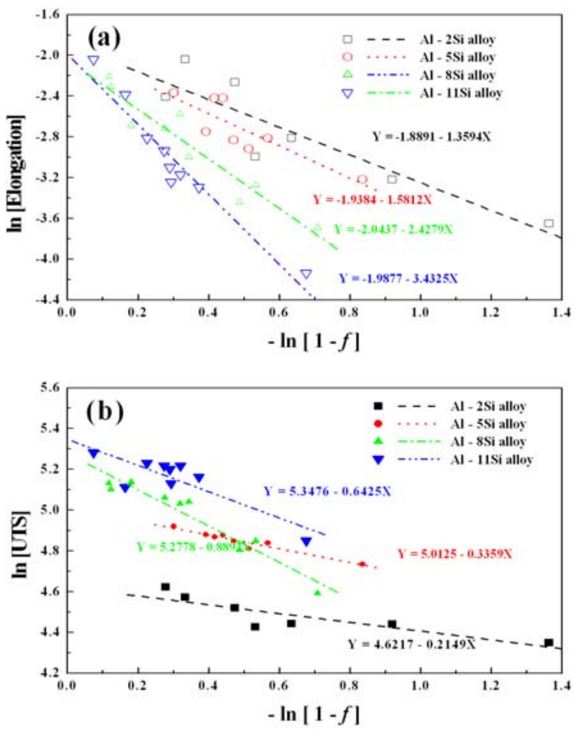

Fig. 3 Tensile properties via defect susceptibility.

Also, the maximum value of UTS achievable in a defect-free condition increases with Si-content, while the elongation is slightly decreased even rarely at similar level.

Figure 4 shows the comparison of theoretical prediction and experimental result. The prediction by modified model [9] show good agreement with experiments and the difference between both approaches means the maximum contribution by micro-failure (cracking mode) of eutectic Si-particles.

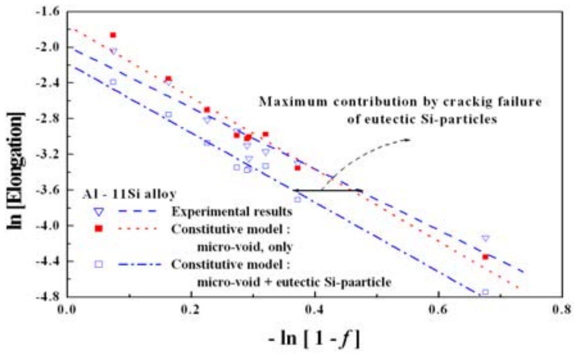

Fig. 4 Typical example of constitutive prediction for contribution of cracking failure of Si-particle.

Acknowledgements

This research was supported by the Development Program for Industrial Core-Technology through the Korea Evaluation Institute of Industrial Technology (KEIT) funded by the Ministry of Trade, Industry and Energy (10048817).

References

[1] C.H.Cáceres: Scripta Metall 32(1995) 1851-1855.
[2] C.H.Cáceres, B.I.Selling: Mat Sci Eng A 220 (1996) 109-116.
[3] A.M.Gokhale G.R.Patel: Mater Char. 54 (2005) 13-20.
[4] A.M.Gokhale, G.R.Patel. Mat Sci Eng A 392 (2005) 184-190.
[5] A.M.Gokhale, G.R.Patel: Scripta Mater 52 (2005) 237-241.
[6] S.G.Lee, G.R.Patel, A.M.Gokhale, A.Sreeranganathan, M.F.Horstemeyer: Scripta Mater 53 (2005) 851-856.
[7] C.D.Lee: Mat Sci Eng A 527 (2010) 3144-3150.
[8] C.D.Lee: Mat Sci Eng A 488 (2008) 296-302.
[9] C.D.Lee, K.S.Shin, Y.G.Kim: J Mat Sci (submitted)