TENSILE FRACURE IN AN Al-Li ALLOY 8090①

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Abstract Tensile fracture of an Al-Li-Cu-Mg-Zr alloy 8090 was studied. The results showed that the tensile fracture of the alloy contains dimples and intergranular rupture as well as cleavage facets, and the cleavage facets are formed by the interaction of inclusions and Na element.

Key words: Al-Li alloy tensile fracture dimple rupture cleavage

1 INTRODUCTION

Al-Li based alloys have been received attention as advanced Al alloys. The addition of Li can increase the specific strength and specific stiffness and decrease the weight of the structure. At present the main problem to limit the application of Al-Li alloys is their low ductility and toughness. A large amount of investigations have been made in China and abroad to solve this problem. The results[1-3] showed that the main reason for low ductility and toughness of Al-Li alloys is coplanar slip and intergranular fracture. We have found that the Al-Li-Cu-Mg-Zr alloy 8090 contains some proportion of cleavage facets besides dimples and intergranular fractures which are common in aluminum alloys. This phenomenon is rare in the *fcc* metals and alloys.

2 EXPERIMENTAL MATERIALS AND METHODS

The material used was 50 mm hot rolled plate supllied by Alcan Company in T651 state. The chemical composition of the alloy (%) was Al-2. 43 Li-1. 17 Cu-0. 74 Mg-0. 12 Zr-0. 09 Fe-0. 09 Si-0. 03 Ti.

The alloy was solution treated in a salt bath at 530 ℃, quenched in water and immediately aged.

Tensile tests were performed in an INSTRON-1186 material testing machine at an initial strain rate of 3.3×10^{-4}/s in laboratory air at 20 ℃ with relative humidity of about 55%.

Tensile fracture was examined in S-550 and S-570 scanning microscopes. Fracture surface compositions were determined in EDAX-9100 energy dispersive spectrometer (EDS).

3 EXPERIMENTAL RESULTS

The alloy in different aging conditions was tensile tested and resultant fracture was examined. The results showed that the alloy is in underaged condition after 190 ℃ 1 h aging. The fracture contains dimples, intergranular rupture and cleavage facets, almost all of the fracture shows dimples. After 190 ℃ 24 h and 150 ℃ 4 h + 230 ℃ 16 h aging, the alloy was in peak aged and overaged conditions respectively. The alloy still contain three parts of fractures above, but large majority of the fracture is intergranular. In these three conditions, the proportion of the cleavave fracture is roughly equal (about 6%). Fig. 1 shows low magnification fracture morphogies of the alloy in different aging conditions.

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High magnification observation shows river patterns on each cleavage fracture surface. The main difference of the cleavage fracture between the Al-Li alloy and common *bcc* alloys (e. g. low carbon steels) is that each cleavage part initiates in large particles (1～10 μm), which is as crack initiation to propagates outside (Fig. 2(a)). It is also observed that the cleavage fracture initiates in large particles on the grain boundary and sub-grain boundary and propagats to one side (Fig. 2 (b)). Pit etching study found square etched pits on the cleavage fracture surface (Fig. 2 (c)), which indicated that the cleavage fracture surface is {100}plane.

EDS analysis on the cleavage fracture had found that the larger particles on the faceted center are (Fe, Cu)Al6, which indicates that the second phase are common inclusions for aluminum alloys. It was also found that the Na

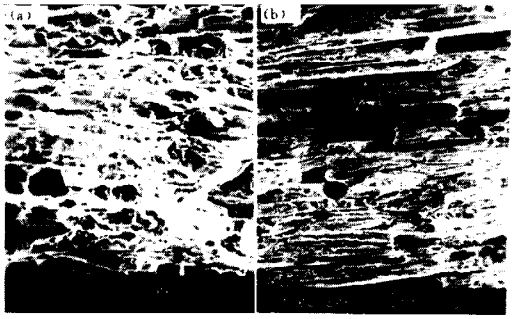

Fig. 1 Low magnification tensile fracture morphologies
(a)—190 ℃ 1 h aging; (b)—190 ℃ 24 h aging

Fig. 2 Cleavage fracture morphologies
(a)—cleavage fracture initiated from center; (b)—cleavage fracture initiated from one side; (c)—square etched pits on cleavage fracture surface

content is abnormal high on the cleavage fracture, and existence of K in some instanse. The area containing Na usually has a distance from the center second phase. The chemical composition for the area 3 ~ 5 μm from the center particles is given in Table 1. From the result it can be seen that there are correlation between cleavage fracture and Na content.

Table 1 Chemical composition on the cleavage fracture(%)

Sample	Cu	Mg	Na	K	Al
1	1.30	0.80	3.87	0.00	94.13
2	1.25	0.75	4.04	0.08	93.90

4 DISCUSSION

As is known that cleavage is the usual fracture mode in *bcc* and *hcp* metals and alloys. In the literature, few observation of cleavage in *fcc* alloys and fewer still in aluminum and aluminum alloys have been reported. The cleavage observation in aluminum alloys involved here liquid metals embrittlement[4, 5], and hydrogen embrittlement or stress corrosion cracking[6—9]. The result here assumes a crack-propagation-agent-induced phenomenon. To validate this assumption, tensile tests were conducted at different strain rates. The results showed that as strain rate increased, the proportion and facet size of the cleavage decreased. This indicates that the effect of Na may be similar to that of H in hydrogen embrittlement. Under the tensile stress, dislocations build up near inclusions to promote local stress concentration. If the Na content is high at this area, it will decrease the cleavage fracture strength so as to induce cleavage crack. During the fracture, Na diffuses into crystal lettice in front of the cleavage crack and decrease the atomic bond strength so as to make the cleavage crack propagates further.

5 CONCLUSION

The Al-Li-Cu-Mg-Zr alloy 8090 exhibits mixed tensile fracture with dimples and intergranular rupture as well as cleavage facets after solution treated and aged, which is seldom seen in *fcc* alloys. The cleavage plane is {100}. The tramp element Na has been identified as embrittling agent.

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