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INVESTIGATION OF MICROSTRUCTURE AND PROPERTIES OF ADVANCED Al-Zn-Mg-Cu ALLOY

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Abstract

The microstructure of a new high strength aluminum alloy (7A55) is preliminarily investigated by TEM, SEM, EDAX and optical microscopy. In comparison with conventional 7000 series high strength aluminum alloys, high strength PM aluminum alloys and Al-Li alloys, the mechanical properties of 7A55 are also investigated. The results show 7A55 alloy has homogeneous microstructure and good properties. Compared with the similar alloys (B96Ц, 7055), its strength and ductility improved slightly, and the specific strength is even higher than most Al-Li alloys. These show its great potential in application to aerospace structural parts for weight saving.

Key Words 7000 series aluminum alloy, microstructure, property

Introduction

With the improved requirement to airplane fighting efficacy and economic benefit, aerospace industry needs much more advanced structural materials. Aluminum alloy, as the main structural material of airplane, is developing into low-density, hot-resistance and high-strength. Because both decreasing density and improving strength can reduce the structural weight, many new low density and high strength aluminum alloys are developed in recent ten years rapidly, such as Al-Li alloys, RS/PM 7090 and 7091 alloys. However, the higher cost limits their application in aerospace. As to this, Alcoa developed IM/7055 super-high strength aluminum alloy in 1991, and it would be applied in Boeing-777 for weight saving. This paper investigates the microstructure and properties of a new high strength aluminum alloy-7A55, which is developed by BIAM (Institute of

Aeronautical Materials, Beijing) for recent years. It has been found that the 7A55 alloy has great potential in application to aerospace.

Experimental Procedures

The alloy investigated was an Al-Zn-Mg-Cu (7000 series) alloy of the following nominal composition (in wt-%): 9.1Zn, 2.4Cu, 2.1Mg, <0.05Fe, <0.05Si, bal. Al. It was suppied by BIAM in the form of semi-continuously DC cast ingot. After proper homogenization, the ingot was extruded to two profiles of the section (dimensions of 11×55mm and ϕ25mm). The heat treatment consisted of the following stages: solution heat treatment, water quenching, natural aging at room temperature, artificial age hardening. The microstructure of the alloy was studied by the JSM-840 scanning electron microscopy (TN-5500 EDAX), H-800 transmission electron microscopy and Neophot-21 optical microscopy. The mechanical properties and SCC (stress corrosion cracking) of 7A55 were tested.

Results and Discussion

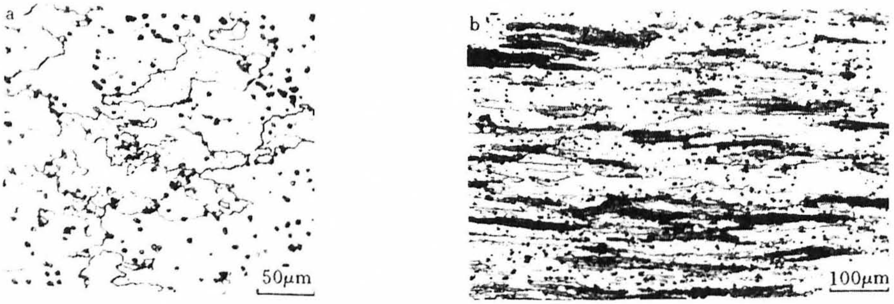

Figure 1. Optical microstructure of alloy 7A55
a—ϕ25mm bar; b—11×55mm extrudate

Figure 1 shows the unidirectionally elongated structure caused by the extrusion process. In artificial ageing temper, the precipitate η' ($MgZn_2$) is dominant, and distributes very homogeneously (Fig. 2a). From Figure 2b, it could be seen that large η precipitates form at the grain boundaries and give rise to a narrow precipitation free zone (PFZ). Figure 2a also shows the homogeneous dispersed α' (Al_3Zr) phase which stabilizes the fine grain structure. This phase is of spherical shape with a diameter about 20nm. There are a little coarse particles (0. 2~0. 5μm) that have been identified as Mg_2Si and $Al_{12}Fe_3Si$ (Fig. 2c, 2d) in this alloy. Generally speaking, the purity of this alloy is very high and it is difficult to find the impurities.

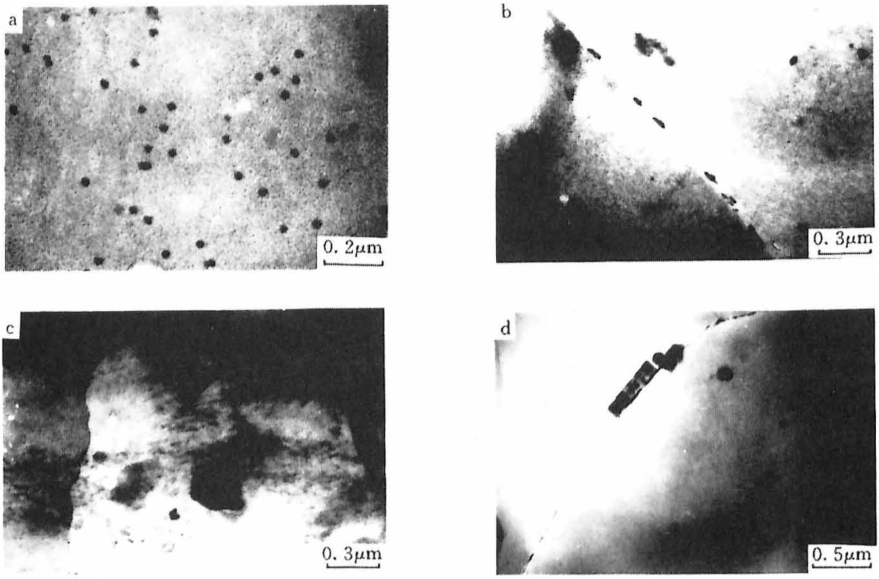

Figure 2. TEM images of alloy 7A55
a—η' +α; b—η; c—Mg_2Si; d—$Al_{12}Fe_3Si$

In artificial ageing temper, transgranular microshearing and ductile dimples are observed (Fig 3a, c, d, e). Microshearing is caused mainly by the special slip behavior of this alloy: In this temper, most of the hardening precipitates are η' type, i. e. they are semicoherent and thus, can be cut by dislocations. This implies planar slip, in combination with high strain concentration along the slip bands. When a critical strain is exceeded, failure by shearing along the slip bands takes place. Ductile dimples are caused by the coarse particles. As the materials is highly alloyed, there are many hardening phase particles which haven't dissolved. They have three patterns—cracking, whitish and grey (Fig. 3b). According to the results of EDAX (Table 1), the first two patterns are all rich in Cu and Zn and the later is rich in Cu only. The impurities which contain Fe and/or Si haven't been found by SEM.

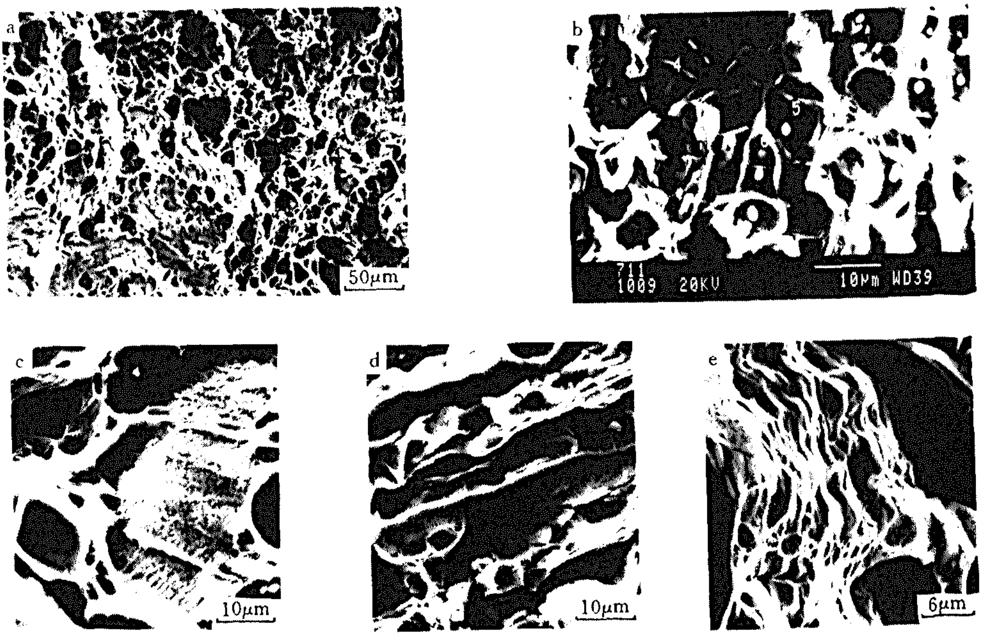

Figure 3. SEM images of alloy 7A55
a—microshearing+dimples; c—shearing feature
d—necking fracture; e—slip bands
b—three kinds of particles
(4# —cracking, 5# —whitish, 6# —grey)

The mechanical and SCC properties of 7A55 and some other high strength aluminum alloys are given in Table Ⅱ [1,2]. It could be found that 7A55 alloy has the highest ultimate and yield strength, combined with satisfactory ductility. Compared with the similar

Table Ⅰ. EDAX Results of Some Particles

Particle	Element Content(wt%)	
4#	30.8Cu	48.4Zn
5#	6.3Cu	16.8Zn
6#	6.4Cu	8.6Zn

alloys (B96Ц, 7055), its strength and ductility are about 5~13% and 23~38% higher respectively. Compared with other high strength aluminum alloys, its strength is also higher. Table Ⅱ also shows the SCC results of 7A55 alloy with different artificial ageing tempers. It bas been found that the SCC behavior and electroconductivity could be improved by heat treatment (the 7A55-CS3 has little SCC).

Table Ⅱ. Properties of Some High Strength Aluminum Alloys Extrudates

Alloy	σ_b (MPa)	$\sigma_{0.2}$ (MPa)	δ (%)	K_{IC} (MPa $\sqrt{m}$)	%IACS	SCC (h)
IM/7A55—CS1	705	681	13	27	32.4	136.5
IM/7A55—CS2	674	662	12		35.5	411.8
IM/7A55—CS3	501	453	12		41.9	/
IM/B96Ц1—T2	670	640	8	57(K_c)		
IM/B96Ц3—T2	610	580	10	100(K_c)		
IM/7055—T77	662	641	10	33		
IM/7150—T77	648	614	12	30		
PM/7090—T7	620	580	9			
PM/7091—T7	595	545	11			

Table Ⅲ. Specific Strength of Some Aluminum alloys Extrudates

Alloy	σ_b(MPa)	δ(%)	ρ(g/cm^3)	Specific Strength (σ_b/ρ)
X2094	720	3.7	2.70	266.7
7A55	705	13	2.89	243.9
7055	662	10	2.85	232.3
B96Ц—1	670	8	2.89	231.8
LC9	645	17	2.80	230.4
7150	648	12	2.82	229.8
2090	565	7	2.59	218.1
B96Ц—3	610	10	2.87	212.5
1450	540	6	2.58	209.3
8090	515	4.2	2.54	202.8

Table Ⅲ lists the specific strength of 7A55 and some other aluminum alloys extrudates.

It could be found that the specific strength of 7A55 is higher not only than LC9 (similar to 7075), B96Ц and 7150, but also than the 2090, 8090 and 1450 Al-Li alloys. This testifies that the 7A55 alloy has good ability on weight saving of airplane.

Conclusions

1. 7A55 alloy which is developed by BIAM is a super high strength wrought aluminum alloy, its ultimate strength at room temperature is higher than 700 MPa.
2. 7A55 alloy has homogeneous microstructure and its main hardening phase is η'. The purity of this alloy is very high, it is difficult to find the impurities such as Mg_2Si and $Al_{12}Fe_3Si$.
3. 7A55 alloy has good coordination of strength, ductility and SCC, its specific strength is higher than the high strength aluminum alloys except X2094 alloy, so it has great potential on weight saving.

References

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2. David A. Lukasak and Ray M. Hart, Advanced Materials & Processes 10, (1991), 46