EFFECT OF TRACE MISCHMETAL ON THE MICROSTRUCTURE AND PROPERTIES OF 2618 ALUMINIUM ALLOY①

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ABSTRACT

The physical, mechanical properties and microstructures of three 2618 Aluminum alloys containing less than 0.046 wt. −% mischmetal have been studied.It has been shown that the trace mischmetal has no obvious influence on the physical properties of the alloy, but can clearly improve plasticity and toughness, and slightly raise the thermal stability.

Key words: mischmetal Aluminium alloy σ_b $\sigma_{0.2}$ δ

1 INTRODUCTION

The 2618 aluminum alloy, a typical heat-stable wrought aluminum alloy, is an important material for plane turbine vanes and other heat-stable parts. With the developement of supersonic planes, it is urgent that the plate material for plane cover can work at 120 ℃ for long period of time. One way to achieve this is to improve the plasticity and thermal stability of the 2618 aluminum alloy[1]. Rare earth elements (Nd, Y, La, Ce, etc.) can improve the casting, corrosion-resistance and thermal stability of magnesium alloys for aircrafts, can also improve the melting quality and fine grains and be beneficial to the heat processing of aluminum alloys. There are many electrolytic aluminum factories that produce rare earth aluminum ingots. It is very difficut to prevent rare earth elements from entering 2618 alloy during its production. It is of concern that what effects the rare earths may have on the microstructure and properties of the alloy. This problem was of great practical and theoretical importance.

2 EXPERIMENTAL AND RESULTS

2.1 *Samples Preparation*

The compositions of the samples are listed in Table 1.

Table 1 The compositions of the samples / wt. −%

NO	R.E*	Cu	Mg	Fe	Ni	Mn	Ti	other	Al
C1	0.004	2.27	1.58	1.10	1.00	<0.2	<0.1	<0.05	bal
C2	0.019	1.98	1.65	1.19	1.05	<0.2	<0.1	<0.05	bal
C3	0.046	1.98	1.71	1.19	1.05	<0.2	<0.1	<0.05	bal

* Mischmetal composed of Ce(≈ 45%), La(≈ 30%) is added in the form of intermediate alloys.

The C1 alloy was an ingot from the workshop, and C2 and C3 were ingots with 172 mm prepared by semi-continuous casting.

The process and heat-treatment conditions of the three kinds of samples were alike. They were. homogenized at 500 ± 5 ℃ for 10 h, extruded into bars with dia. 25 mm at 450 ℃, water-quenched after heating at 530 ± 5 ℃

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for 90 min, and aged at 185 ± 5 ℃ for 8 h.

2.2 *Test of Physical Properties*

The melting temperature (error ± 0.5 ℃) and thermal expansion coefficient were measured with a Japan Ricon Thermal Analysis Station. The thermal conductivity(error ± 0.5 %) was measured using a JR−2 laser pulse thermal conductivity instrument, and electrical conductivity (error ± 1 %) was measured by an eddying conductivity gauge. Table 2 shows the results.

Table 2 · The results of the typical physical properties

No	T_m / ℃①	α_l / $\times 10^{-6}K^{-1}$②	χ / $W \cdot m^{-1} \cdot K^{-1}$③	σ / %IACS④
C1	604.8~630.5	21.7	134	33.0
C2	559.5~634.1	22.1	133	32.8
C3	604.3~631.4	22.4	137	31.8

① T_m—melting point; ② α_l—thermal expansion coefficient at 25 ℃; ③ χ—thermal conductivity at 25 ℃; ④ σ—electric conductivity at 25 ℃

2.3 *Test of Mechanical Properties*

Some routine mechanical properties were measured at room temperature by a WD−10A Electronic Tensile Machine. The results are listed in Table 3 (error ± 1 %).

Table 3 Routine mechanical properties at room temp.

NO	σ_b / MPa	$\sigma_{0.2}$ / MPa	δ / %	HB / S10 / 500	E / GPa
C1	419	324	14.6	172	64
C2	395	267	22.6	165	64
C3	401	269	22.2	168	64

The shearing strength σ_τ, shock toughness a_{KV} and fracture toughness are shown in Table 4, where K_{IC} was determined using circular notched samples[2].

Using comparing tests, the rotating fatigue life and tensile-compressive fatigue life were measured respectively according to HB 5152−80.

Both tests were carried out at room temperature and $R=-1$. For the rotating fatigue test, revolution rate was 3,000 r / min and the stress value 180 MPa for each group of samples. For the tensile-compressive test, loading frequency was 120 N / min and the stress value was the $\sigma_{0.2}$ of each group of samples respectively (see Table 5).

According to reference [3], the logarithm of tensile-compressive fatigue life conforms to a normal distribution when the cycling number is below 10^6. The results of each fatigue life N_f and mean fatigue life N_{50}, where

$$N_f = \frac{1}{n}\sum_{i=1}^{n} N_i,\quad \log N_{50} = \frac{1}{n}\sum_{i=1}^{n} \log N_i$$

are listed in Table 5.

The instantaneous tensile properties of the alloy at elevated temperatures are listed in Table 6.

Table 4 The results of σ_τ, a_{KV} and K_{IC}

NO	σ_τ / MPa	a_{KV} / J · cm^{-2}	K_{IC} / MPa · $m^{1/2}$
C1	229.3	26.5	24.6
C2	231.6	28.3	25.0
C3	241.3	30.6	25.1

Table 5 Results of fatigue life

NO	rotating		tensile-compressive	
	N_f	N_{50}	N_f	N_{50}
C1	8.79×10^5	3.19×10^5	34539	34002
C2	9.17×10^5	9.00×10^5		
C3	1.06×10^6	1.05×10^6	40371	37391

Table 6 Instantaneous tensile properties of the alloys at elevated temperature

NO	150 ℃			200 ℃			250 ℃		
	σ_b / MPa	$\sigma_{0.2}$ / MPa	δ / %	σ_b / MPa	$\sigma_{0.2}$ / MPa	δ / %	σ_b / MPa	$\sigma_{0.2}$ / MPa	δ / %
C1	358.7	260.7	18.1	324.3	241.3	17.4	252.3	218.3	10.7
C2	360.7	235.0	26.3	317.3	218.7	21.7	251.3	221.7	14.5
C3	351.7	220.3	25.2	314.7	213.3	23.7	251.7	219.0	14.1

The creep and endurance properties of C2 alloy were measured at 200 ± 3 ℃ for100 h.

For the creep, $\sigma^{200}_{0.2/100} = 166.5$ MPa when using the regression method; or 167 Mpa when using the logarithm diagramming method. The creep limit range was 166~167 MPa.

For the endurance, $\sigma^{200}_{100} = 199$ MPa when using the regression method, or 190~195 MPa when using the logarithm diagramming method. Thus, the endurance of C2 alloy was

between 190～195 MPa.

The composition and microstructure of the phase containing rare earth elements were analyzed with a H–800 type TEM. Table 7 indicates the compositions of rare earth compounds and Fig. 1 shows the TEM micrographs of C3 alloy, where the phase dispersion-distributed at the boundary and in the grain is the rare earth compound.

Table 7 The compositions of R.E. compound / wt. –%

Element	Mg	Al	Si	Ca	La	Ce	Fe	Ni	Cu
Phase Ⅰ	1.29	76.86	0.14	0.72	0.07	0.03	8.35	9.38	3.16
Phase Ⅱ	0.47	87.91	–	–	–	0.27	1.70	2.01	7.57

3 DISCUSSION

With the increasing of mischmetal content, the difference in melting temperature is less than 5 ℃; the thermal expansion coefficient increases a bit; the thermal conductivity changes little; and the electrical conductivity decreases slightly.

Among the above four physical properties, because the sample for melting temperature test is small (10 g), and the composition deviation is inevitable, the melting temperature shows a little fluctuation. Although the thermal expansion coefficient increases slightly, it still conforms to international standards[4]. The reason why the electrical conductivity decreases slightly is that the heat-resisting strengthening phase $FeNiAl_9$ is distributed more dispersively in the grains and at the boundary because of the effect of rare earth elements.

An alloy containing less than 0.005 wt. –% rare earth elements is considered to be without them during production. So, C1 alloy is considered an alloy without rare earth elements. It can be seen from Table 3 that, after adding rare earth elements. to C2 and C3 alloys, their standard mechanical properties σ_b, $\sigma_{0.2}$ and HB at room temperature decrease, but their plasticity δ obviously improves. It is worth noting (see Table 4) that, with the increasing of mischmetal content, shearing strength σ_τ, shock toughness a_{KV} and fracture toughness of the alloys increase. The above results show that trace mischmetal can improve the plasticity and toughness of the 2618 alloy, which is favourable for its processing and service.

With reference to Table 5, rare earth elements has improved the fatigue which can be withstood by the alloy property at room temperature, which is closely related to its toughness. The improvement in the tolerance of fatigue is significant for aircraft materials.

The strength of C1 is better than those of

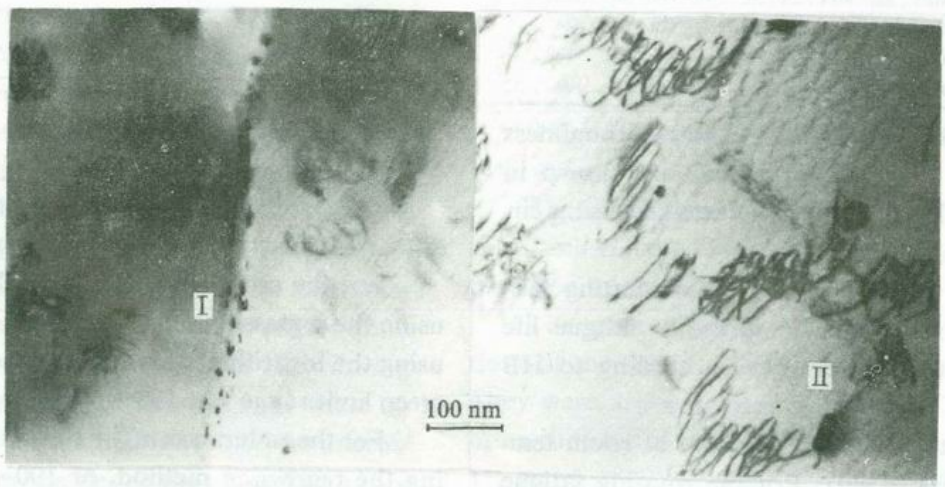

Fig. 1 TEM micrographs of R.E. compound dispersion-distributed at boundary (left) and in grain (right)

C2 and C3, but σ_b and $\sigma_{0.2}$ of C2 and C3 are nearly the same as or better than those of C1 at 150, 200 and 250 ℃. At the same time, their δ value remains rather high (Table 6).

The creep limit and endurance of C2 alloy at elevated temperature reached $\sigma^{200}_{0.2/100} = 165$ MPa and $\sigma^{200}_{100} = 195$ MPa, respectively, which conform to international standards[4].

The main phases of the 2618 alloy are α+S+$FeNiAl_9$. There may exist Al_7Cu_2Fe when Fe > Ni[5]. The thermal stability of the alloy depends on aging strengthening of the S phase dissolved in the matrix and dispersion distributed strengthening of $FeNiAl_9$ or Al_7Cu_2Fe (neither dissolve in the matrix). According to the data in Table 7, phase Ⅰ is $FeNiAl_9$. Phase Ⅱ may be Al_7Cu_2Fe (in C3 alloy Fe > Ni), where Ni partially replaces Fe, which is normal in metallurgical observation of aluminium alloy[5]. There exist rare earth elements in both phases Ⅰ and Ⅱ. Which show rare earth elements can compound with heat-stable strengthening phases in the 2618 alloy. From Fig. 1, these phases mainly dispersively distribute along the boundaries and impede the movement of dislocations. These phases are smaller in grains and the density of dislocation lower, which may be caused by the trace mischmetal. This leads to slight decreases in the strength of the alloy but clear increases in its plasticity and toughness at room temperature. The dispersion-distributed phases do not dissolve at elevated temperature, thus improving the thermal stability.

From all the above analyses, we can see that trace mischmetal less than 0.046 wt. −% has no harmful effect on the physical and mechanical properties of 2618 alloy, but can clearly improve some of the mechanical properties. What effect adding more mischmetal has on the properties of the alloy is a significant subject worthy of further reseach.

4 CONCLUSIONS

Adding less than 0.046. wt. −% trace mischmetal to 2618 alloy has the following effects on its properties:

(1) The trace mischmetal has no obvious effect on the melting temperature and thermal conductivity at room temperature but can slightly increase the average thermal expansion coefficient (20～200 ℃), and decrease the electrical conductivity at room temperature;

(2) The traces of mischmetal slightly decrease the strength of the alloy at room temperature improving clearly increase its plasticity, shearing strength, shock toughness, fracture toughness and fatigue life, thus improving the plasticity and toughness of the alloy;

(3) Trace mischmetal can compound with heat-stable strengthing phase dispersion-distributed in the matrix and improve the thermal stability.

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