# CREEP BEHAVIORS OF Pt–RE ALLOYS AT HIGH TEMPERATURES①

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## ABSTRACT

The creep behaviors of Pt–RE alloys have been studied at 1 200 ℃ and 1 400 ℃. The results show that a small amount of RE elements improves the creep behaviors of platinum greatly. The creep behaviors of PtGd0.5, PtLa0.5 and PtLa0.3 Gd0. 2, are best among all the alloys studied. As far as the creep behaviors are concerned, the traditional heat-resistance alloy PtGd10 can be replaced by PtGd0.5. Particularly, the properities of PtGd0.5 are near to those of PtRh10. For most of the Pt-RE alloys, long-time, static, super high-temperature treatment in air is of no advantage to the creep rupture life. The mechanisms of the effects of rare-earths on high-temperature creep properties of platinum are discussed.

**Key words:** Pt–RE alloys high-temperature creep behaviors

## 1 INTRODUCTION

Rare-earths have good effects on the structures and properties of heat-resistant alloys and, therefore, improve the creep resistance and oxidation resistance behaviors enormously[1, 2]. We have tried to find a new kind of heat-resistant alloy for use in the glass fibre industry by adding RE elements into platinum base alloys. Reducing the cost of the alloys and improving the high-temperature creep properties are the aims of the work. First, we studied the mechanical and electrical properties of Pt–RE alloys[3, 4]. We report the high-temperature creep behaviors of Pt–RE alloys in this paper.

## 2 EXPERIMENTAL

The purities of platinum and rare-earths were 99. 95% and 99. 9% respectively. They were melted by a high frequency induction furnace. The ingots of the alloys were cold-worked into 0.3 mm dia wires. For comparison, the alloy PtRh10 was tested. The creep tests were conducted in a furnace consisting of a MoSi heat generating tube, an automatic timer and a control system. The range of homogeneous temperature in the furnace was about 30 mim, in which the change of temperature is less than 5 ℃.

## 3 EXPERIMENTAL RESULTS

According to the relationship between creep rupture life $\tau$ and creep stress $\sigma$, we have $\tau = A\sigma^{-n}$, where $A$ and $n$ are constants. We can get another form for the above equation $\lg\tau = \lg A - n\lg\sigma$. From this equation, we can see that the relationship between $\tau$ and $\sigma$ is a straight line in a double –logarithmic coordinate system.

Fig. 1 gives the relationships between $\tau$ and $\sigma$ of some platinum-rare earth alloys. It is seen that the creep rupture life drops with descending creep stress in straight or broken lines.

From the above figure, we can obtain the creep rupture life ($\tau_{10}$) for a creep stress of 10 MPa and creep rupture strengths ($\sigma_1$, $\sigma_{10}$, and

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$\sigma_{100}$) for the rupture lives of 1, 10 and 100 respectively. The related data are listed in Table 1 for all the alloys. It is seen from Table 1 that the values of $\tau_{10}$ for Pt(RE)0.5 alloys are far larger than those for platinum, and the alloys of Pt(RE)0.5 are 2～4 times larger than platinum in $\sigma_1$, $\sigma_{10}$, and $\sigma_{100}$. The high temperature creep properties of PtGd0.5 are the best and are almost as good as that of PtRh10. Therefore, as far as the high temperature creep behaviors are concerned, the traditional heat resistant alloy PtRh10 used in the glass fibre industry can be replaced by PtGd0.5. The creep properties of PtLa0. 5 are better at 1 400℃. However, the alloys PtGd1 and PtLa1 which contain more rare-earths, have poor creep properties. The $\tau_{10}$ for PtLa0.3Gd0.2 is larger and this shows that Pt−poly−RE alloys are worth studying.

The constant $n$ can be calculated from Fig. 1 (See Table 1). It is noted that, for the broken line in Fig. 1, $n$ increases with decreasing creep stresses. This is another precious property of Pt−RE alloys.

For most of the Pt−RE alloys and PtRh10, long-time, static, super high-temperature treatment in air is of no advantage to the creep rupture life, with the exception of PtLa, PtEr and PtYb (See Table 2). The decrement of $\tau_{10}$ of PtSm is the largest.

## 4 DISCUSSION

The actual rare-earth contents of Pt−RE alloys studied in this work are less than 0.3% according to chemical analysis. Other researchers' results show that the solubility of rare-earths in platinum increases with increasing temperature[5]. For example, the solubilities of Y in platinum are 0.105% and 0.26% at 1 200 ℃ and 1 400 ℃

**Table 1 The high-temperature creep behaviors of Pt−RE alloys**

| Alloy number | Alloy | 1 200℃ | | | | | 1 400℃ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\tau_{10}$/h | $\sigma_1$/MPa | $\sigma_{10}$/MPa | $\sigma_{100}$/MPa | $n$ | $\tau_{10}$/h | $\sigma_1$/MPa | $\sigma_{10}$/MPa | $\sigma_{100}$/MPa | $n$ |
| 0 | Pt | 0.55 | 8.30 | 3.80 | 1.75 | 4.9, 3.0 | 0.015 | 3.40 | 1.80 | 0.97 | 3.7 |
| 1 | PtLa0.5 | 9.1 | 17.30 | 10.00 | 5.78 | 4.2 | 0.77 | 9.40 | 5.18 | 2.87 | 3.9 |
| 2 | PtNd0.5 | 19.1 | 18.20 | 11.30 | 6.93 | 4.7 | 0.57 | 8.80 | 4.72 | 2.49 | 3.6 |
| 3 | PtSm0.5 | 7.4 | 16.80 | 9.95 | 5.90 | 4.4 | 0.38 | 7.54 | 4.00 | 2.11 | 3.6 |
| 4 | PtEu0.5 | 8.9 | 17.00 | 10.00 | 5.85 | 4.3 | 0.32 | 8.40 | 5.20 | 3.25 | 4.9 |
| 5 | PtGd0.5 | 22.1 | 19.50 | 11.80 | 7.58 | 4.1, 5.2 | 0.63 | 9.95 | 6.50 | 4.28 | 5.5 |
| 6 | PtEr0.5 | 9.0 | 16.60 | 10.00 | 6.06 | 4.6 | 0.23 | 7.30 | 4.35 | 2.61 | 4.5 |
| 7 | PtYb0.5 | 16.8 | 17.90 | 11.20 | 7.25 | 4.2, 5.3 | 0.23 | 7.90 | 4.80 | 2.94 | 4.7 |
| 8 | PtY0.5 | 15.6 | 19.00 | 11.00 | 6.27 | 4.1 | 0.27 | 6.80 | 4.74 | 3.31 | 3.1, 6.4 |
| 9 | PtRh10 | 35.1 | 24.60 | 14.20 | 8.31 | 4.3 | 3.44 | 13.60 | 8.00 | 4.68 | 4.3 |
| 1−1 | PtLa1 | 1.4 | 10.80 | 7.40 | 5.60 | 5.1, 8.2 | 0.058 | 5.16 | 3.02 | 1.77 | 4.3 |
| 5−1 | PtGd1 | 1.9 | 11.70 | 6.40 | 5.21 | 3.7, 11.2 | 0.065 | 4.26 | 2.10 | 1.00 | 3.1 |
| 19 | PtLa0.3Gd0.2 | 21.7 | | | | | 0.69 | | | | |
| 20 | PtLa0.3Y0.2 | 10.3 | | | | | 0.31 | | | | |
| 21 | PtGd0.3Y0.2 | 5.0 | | | | | 0.072 | | | | |

**Table 2 The effect of high-temperature treatment in air (1 400 ℃, 13 h) on the creep rupture life $\tau_{10}$ (h) of Pt−RE alloys and PtRh10**

| Alloy number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Before oxidation | 0.77 | 0.57 | 0.38 | 0.32 | 0.63 | 0.23 | 0.23 | 0.27 | 3.44 |
| After oxidation | 0.82 | 0.45 | 0.067 | 0.27 | 0.31 | 0.24 | 0.31 | 0.083 | 1.60 |

respectively. As we know, the average atomic radius of RE elements is 30% larger than that of Pt. Therefore, the RE atoms dissolved in Pt can produce great distortions in the atomic lattice of the Pt base. The motions of dislocations are impeded by this great distortion stress field, and thus the creep resistance of grains is improved. Moreover, Pt and RE elements form Pt–RE compounds easily because there are large differences in electronegativity between Pt and RE atoms[6]. Oxygen, which has a great affinity for RE elements, diffuses into the grains along the slide systems of Pt under the actions of creep stress at high temperatures, and thus RE oxides are formed (See Fig. 2). These Pt–RE compounds and RE oxides which distribute dispersively in the Pt base are advantageous to slow the creep strain of the alloys.

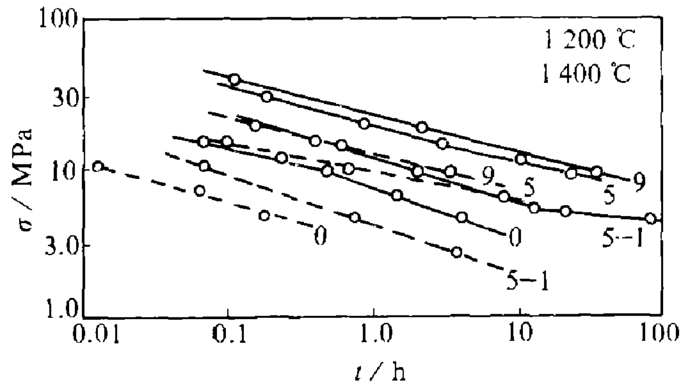


**Fig.1 The relationship between the creep rupture lives(τ) and the stresses(σ)**

O—Pt; 5—PtGd0.5; 5–1—PtGd1; 9—PtRh10

solid line—1 200 ℃; dashed line—1 400 ℃

For high-temperature creep, the properties of grain boundarie are very important[8]. Due to the atomic size effect, the solute atoms aggregate on the grain boundaries easily[9]. The aggregated RE atoms form Pt–RE compounds and RE oxides with Pt and oxygen respectively which can impede the glutinous flow of grain boundaries and thus the grain boundaries are strengthened.If the RE contents of the alloys increase, more RE atoms aggregate on the grain boundaries, and the net structures of Pt–RE compounds and RE oxides form quickly. This structure is harmful to the creep behaviors of the alloys. Oxygen atoms diffuse into the inner platinum grains with difficulty while the static high-temperature treatment forms Pt–RE alloys. Oxygen diffusing along the grain boundaries forms oxides with rare-earth elements aggregated on the grain boundaries. The oxides grow with the time (see Fig. 3), and this is of no advantage to the creep behaviors of the alloys.

**Fig.2 Creep microstructure of PtGd0.5 (1 372℃)**

The distributions of electrons of Gd and La atoms are different from those of other rare-earth atoms The 4*f*-orbit is empty or half–full in the stable states, while there is one electron in the 5*d*–orbit. The excellent high-temperature creep behaviors of PtGd0.5. PtLa0.5 and PtLa0.3 Gd0.2 are probably related to the special distributions of electrons of Gd and La atoms.

The creep life is sensitive to creep stress, which is indicated by constant *n*. The increments of *n* at lower stresses reflect the formations of rare-earth oxides.

## 5 CONCLUSIONS

(1)A small amount of rare-earth elements improves the high-temperature creep behaviors of platinum greatly. PtGd0.5, PtLa0.5 and the PtLa0.3Gd0.2 have excellent high-temperature creep properties among all the Pt–RE alloys tested. As far as the high-temperature creep behaviors are concerned, the alloy PtRh10 can be replaced by the alloy PtGd0. 5;

(2)Long-time, static treatment at super high temperatures in air is harmful to the high-temperature creep behaviors of most of the Pt—RE alloys and the alloy PtRh10;

**Fig.3 The distribution of RE oxides of PtEu0. 5 along the boundaries after 13 h of static inner oxidation in air at 1 400 ℃**

(3)Rare-earth atoms dissolved in platinum base, Pt—RE compounds and rare-earth oxides improve creep resistance, Pt—RE compounds and rare-earth oxides formed by RE atoms aggregated on the grain boundaries impede the glutinous flow of grain boundaries, and thus the grain boundaries are strengthened. These are the main causes for the fine high-temperature creep behaviors of Pt—RE alloys.

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