” Fatigue Reliability Evaluation and Fracture Analysis at Elevated Temperature related to Safety Guarantee of Industrial Use Pt Alloy”

Soichi HITOMI*, Hideto SUZUKI, Masashi NAKAMURA****

* Tanaka Kikinzoku Kogyo K.K. Isehara Works , 26, suzukawa ,
Isehara-city, Kanagawa, 259-1146 JAPAN
** Department of Engineering, Faculty of Engineering, Ibaraki University ,
4-12-1, Nakanarusawa, Hitachi-City, Ibaraki, 316-8511 JAPAN

ABSTRACT

Platinum and its alloys are widely used in the glass-melting industry because of their high melting point, high resistance to oxidation and inertness with molten glass. Since they are usually used above 1273K, it is important to improve their mechanical properties at high temperatures above 1273K. Alloying with rhodium is known as a conventional method to increase the strength of platinum. For the further improvement of high temperature properties, it is essentially important to clarify the basic mechanical properties of platinum and its alloys at elevated temperatures.

In this study, fatigue reliability at elevated temperature of platinum and its alloys were examined by the elucidation of fracture mechanism. Main results were follows ; (1)S-N characteristics of PtRh alloys were almost arranged in the straight line. (2) From the fractography using SEM, it was indicated that fatigue fracture mechanism was similar to the static destruction in the high stress side, on the other hand, that was effected by creep in the low stress side.

KEYWORDS

Fatigue fracture, Fractography, Platinum, High temperature, Creep

INTRODUCTION

Platinum is one of the precious metals which are representative as well as the gold. Platinum is used as not only decorative material but also industrial material. Platinum and its alloys are widely used in the glass melting industry because of their high melting point, high resistance to oxidation and inertness with molten glass. Therefore, platinum and its alloys are indispensable to the manufacturing of the high-grade glass.

Equipments used for glass melting generally be broken by creep rupture mechanism because it usually last for long time under high temperatures. Especially, the thermal fatigue by rapid temperature change occurs at temperatures higher than 1273K when raw materials are fed into the glass-melting crucible. However, the report on high temperature creep property and fatigue characteristics of platinum and its alloys are little still. Therefore, it is very important to grasp fracture characteristics of platinum and its alloys.

In this study, high temperature fatigue reliability of platinum alloy was demonstratively examined including the elucidation of fracture mechanism.

EXPERIMENTAL PROCEDURE

The materials used for the test are industrial grade purity platinum, industrial use Pt-10wt%Rh alloy and ZrO_2 dispersion strengthened platinum.

Industrial grade purity platinum and industrial use Pt-10wt%Rh alloy ingots were hot forged at 1473K. After they were forged, they were cold rolled to 10mm thickness and annealed at 1373K for half an hours. Then they cold rolled to 1mm thickness.

ZrO_2 dispersion strengthened platinum ingot was hot forged at 1473K. After it was forged, they were cold rolled to 10mm thickness and annealed at 1673K for an hour. Then they cold rolled to 1mm thickness.

Specimens were punched from the sheets. Their dimensions were 2.5mm wide and 20mm long. The surface was polished with alumina powder, and it was finished in the specularity.

The fatigue test was carried out in 20Hz frequency, sine wave of R=0.1 stress ratio, in the vacuum at room temperature and 1073K under the load control.

RESULTS AND CONSIDERATION

S-N chart

Relationship between rupture number of cycles (Nf) and stress amplitude (S) of the PtRh alloy explained above was measured in the vacuum at 293K and 1073K. The results are summarized in Figure-1. S-N characteristics of the PtRh alloy was regressed as the straight line. Fatigue strength of the specimen defined as stress amplitude at 10^7 cycles was 100MPa at 293K and 30MPa at 1073K.

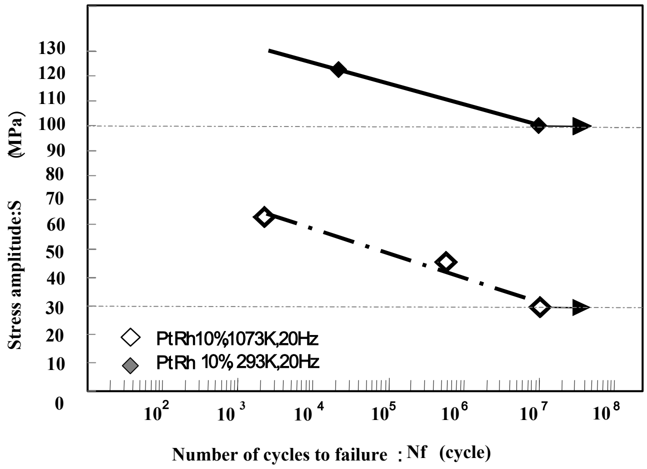
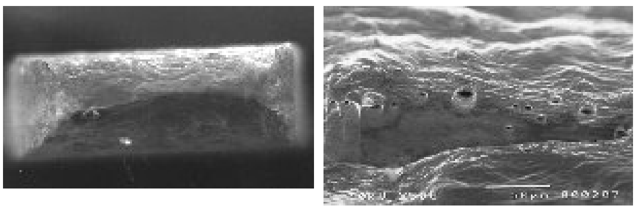


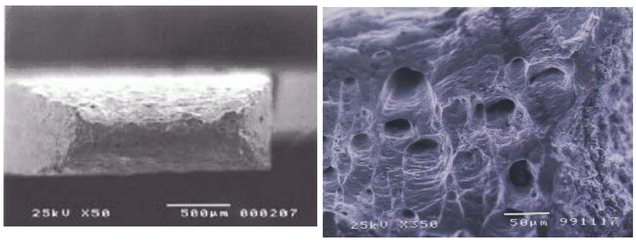
Fig.1 S-N curve of PtRh material

SEM observation and analysis of the specimen done fatigue breakdown at 1073K

Fracture surface analysis was carried out for the specimens after they broke in order to clarify high temperature fatigue characteristics of the PtRh alloy.

Fracture surface photograph in short life (S=60MPa, 1073K) is shown in figure 2. Figure 2(a) is low magnification, and (b) is a fracture surface of high magnification. From figure 2(a), there was sliding necking in the fracture surface, and it was proven to be the typical ductile fracture.





(a)Low magnification (b)High magnification (a)Low magnification (b)High magnification

Fig.2 SEM photograph of fracture surface (S=60MPa) Fig.3 SEM photograph of fracture surface (S=45MPa)

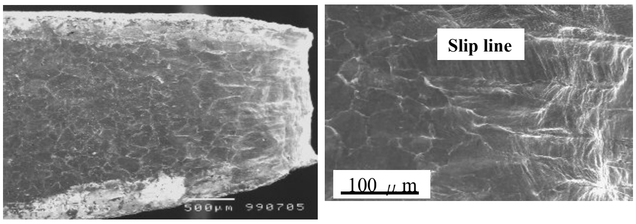
Fracture surface photograph in long life (S=45MPa, 1073K) is shown in figure 3. Figure 3(a) is at low magnification, and (b) is a fracture surface of high magnification. From figure 3(a), there was sliding necking in the fracture surface, and it is considered to be ductile fracture. Different from the fracture surface of short life sample shown in figure 2(b), a lot of dimples were observed on entire fracture surface of long life sample as shown in figure 3(b).

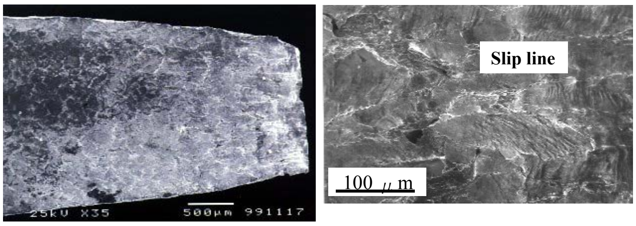
It is assumed through the phenomena that creep deeply affected dimple generation and they were made under conditions of dynamic fatigue breakdown. There is a transition of the failure mechanism that effect of creep increases with decrease of stress. In other words, in the high stress condition, it is similar to the static destruction, and it is indicated that the effect of the creep is big in the low stress condition. There was a difference of failure mechanism in high stress (short life) and low stress (long life).

The elucidation of the failure mechanism by the surface observation

Figure 4(a) and (b) show SEM photographs of the specimen surface which utilized in high stress (S=60MPa, 1073K) fatigue test. Figure 4(a) is at low magnification, and (b) is the specimen surface of high magnification. Slip lines were observed in the grains located up to around 800 microns from the rupture edge. Thickness of the specimen begun to decrease from the 800-micron point toward the rupture edge, namely necking occurred. In order for comparison with this, surface of sample ruptured at S=45MPa is shown in Figure 5. Figure 5 indicated that the thickness of the sample begun to decreased at around 300 micron away from the rupture edge. This result is different from the result of conducting at s=60MPa fatigue test. The effect of sliding in the grain differs in high stress (short life) and low stress (long life).

Rupture surface photograph of the high magnification is shown in figure 5(b). Opening of grain boundary that can be starting point of fracture was observed The high magnification rupture surface photograph at 30MPa is shown in figure 6. There was a grain boundary cracking, too. According to the result of rupture surface observation and fracture surface observation, the grain boundary fracture was generated by the effect of the creep in the lower stress side.





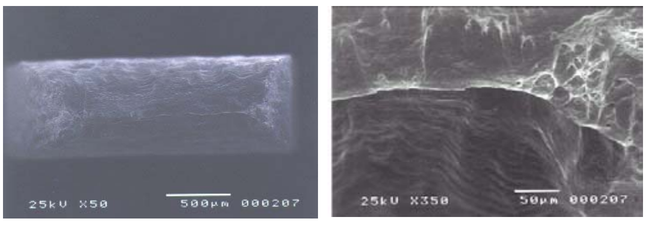
(a)Low magnification (b)High magnification (a)Low magnification (b)High magnification

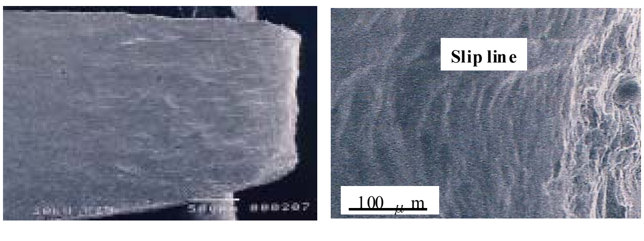
Fig.4 SEM photograph of the specimen surface (S=60MPa) Fig.5 SEM photograph of the test piece surface (S=45MPa)

Fig.6 SEM photograph of the specimen surface (S=30MPa)

SEM observation and analysis of the specimen done fatigue breakdown at 293K

Specimen surface photographs in short life (S=120MPa) are shown in figure 7(a), (b), and fracture surface photographs are in figure 8(a),(b). As seen in figure 7(a) and (b), there was sliding necking. There was sliding in the grain on the fracture surface shown in figure 8(b). Therefore, this seems to be also the ductile fracture.





(a)Low magnification (b) High magnification (a)Low magnification (b) High magnification

Fig.7 SEM photograph of specimen surface (S=120MPa) Fig.8 SEM photograph of fracture surface (S=120MPa)

CONCLUSIONS

Fatigue test on the Pt-10wt%Rh alloy at 293K and 1073K were performed. Fatigue strength of Pt-10wt%Rh were 100MPa at 293K, and 30MPa at 1073K. It had broken in ductile fracture at both temperature range, and it was proven that the sliding in the grain was dominant for the deformation of the PtRh alloy. In low stress, high temperature side, there would be the effect of the creep, and there were crack and opening in the grain boundary.

Fatigue breakdown behavior of pure-Pt and ODS-Pt is under investigated.

REFERENCES

(1) K. Kikuchi, Y. Kaji, Y. Muto, S. Kitade, Trans.JSME, 59-557, A (1993-1), pp94-99
(2) R. Ohtani, T.Kitamura, M.Tsutsumi, H. Miki, Trans.JSME, 59-560, A (1993-4), pp933-938
(3) T.Kitamura, R. Ohtani, W. Zhou, M. Yamada, N. Iizuka, Trans.JSME, 59-566 A (1993-10), pp2234-2240
(4) H.Suzuki, S. Numata, K. Katahira, Trans.JSME, 63-616 A (1997-12), pp2679-2685
(5) H.Suzuki, S. Numata, S. Nishino, Trans.JSME, 63-610 A (1997-6) ,pp.1141-1146
(6) S. Numata, K. Katahira, H.Suzuki, Trans.JSME, 64-619, A (1998-3) pp.597-602
(7) T. Hamada, thesis, Osaka Univ. (1998)
(8) T. Hamada, S. Hitomi, T. Nishimori and S.Nasu, THERMEC'97 International Conference on Thermomechanical Processing of Steels and Other Materials, (1997), pp.1647-1653