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High-temperature bending fatigue properties of oxide dispersion-strengthened platinum–rhodium alloy under high axial stress

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ABSTRACT

In this study, high-temperature bending fatigue tests were carried out using an oxide dispersion-strengthened platinum-rhodium alloy at 1400 °C with a relatively high axial stress. At a low stress amplitude, creep damage progressed throughout the cross-section of the sample due to axial stress. However, at a high stress amplitude, creep damage progressed only in the central part of the direction of thickness and fracturing originated from inside the sample. Elastic-plastic creep analysis also indicated that high tensile stress remained inside the sample due to the yielding near the surface. The fact that the life is determined by the creep due to the stress generated inside of the material is useful for life prediction.

1. Introduction

Platinum alloys are used widely in industrial applications such as fuel cell electrodes and catalysts for removing harmful substances from automobile exhaust gas [1]. They are also employed widely in glass manufacturing processes in components such as melting crucibles and stirrers because they exhibit excellent resistance to molten glass at high temperatures as well as high oxidation resistance. Their range of application continues to expand due to the development of high-quality glasses that are difficult to melt, such as the glass used in liquid crystal display panels. This type of glass is produced at high temperatures, and thus the platinum alloys employed are required to have high strength. Therefore, a platinum–rhodium alloy strengthened with about 10 wt% of rhodium solid solution is used, while oxide dispersion-strengthened (ODS) platinum alloys have also been developed and applied to satisfy even higher strength requirements [2,3]. ODS platinum alloys are materials comprising zirconium oxide particles dispersed in platinum or a platinum–rhodium alloy matrix, where the dispersed particles enhance the high-temperature strength, suppress the grain growth, and impart long-term stable characteristics [4]. These components are very expensive and the longest possible lifetime with the least amount of usage is required, so it is necessary to extend the lifetime while also considering the production cost. In particular, a melting crucible with a stirrer is a complex environment where hoop stress is generated by the internal pressure from the molten glass on the wall of the melting crucible and pressure fluctuations occur due to the movements of the stirrer blade. It is assumed that the hoop stress due to the internal pressure by the molten glass causes creep damage and that the repeated bending stress because of pressure fluctuations leads to fatigue damage. However, it is very difficult to estimate the lifetime accurately because it is necessary to examine the interaction between creep and fatigue. Few data are available regarding the mechanical properties of these alloys at high temperatures, although some studies have investigated their creep properties under high temperature fatigue [4–6]. Thus, the effects of the mean interparticle distance and grain aspect ratio with respect to high-temperature fatigue have been investigated, and it was shown that the fatigue strength is greater when the mean interparticle distance is smaller and the grain aspect ratio is larger [7]. However, the interaction between creep and fatigue remains unclear. Therefore, it is difficult to estimate the effects of the hoop stress due to the internal pressure from the molten glass and the cyclic bending stress because of the rotation of the stirrer on the lifetime of the platinum alloy container used in the stirring process.

The interactions between creep and fatigue have been investigated extensively at high temperatures for Ni-based alloys, ODS-Ni-based alloys, and stainless steels, and methods for predicting their lifetimes have also been developed [8–15]. In these studies, the relationships between creep, fatigue damage additivity, and fracture morphology were determined using the linear damage rule and ductility exhaustion rule, and the effects on the lifetime of the materials because of hardening due to repeated loading were determined. However, the operating temperature range for these alloys is limited to about 60% of the

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