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Interaction of hot corrosion and creep in Alloy 617

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ABSTRACT

In the present work, Alloy 617 was subjected to creep in the absence and presence of hot corrosion (i.e. with and without a deposit of sodium salts) under different load magnitudes at 850 °C. Additionally, a sample of the alloy was exposed to hot corrosion without applying creep. The results revealed that the creep behavior of Alloy 617 was substantially affected by hot corrosion which accelerated creep and led to a considerable reduction in the fracture ductility and creep life of the alloy. Microscopic examinations demonstrated that the strain-to-rupture decreased due mainly to the damage accumulation during tertiary creep. Various mechanisms of hot-corrosion/creep interaction were discussed that highlighted the destructive role of $M_{23}C_6$ precipitates in the interaction. It was explained that hot corrosion contributed to the reduction of grain-boundary cohesive-strength followed by extensive cavitation at transvers grain boundaries.

1. Introduction

Alloy 617 (UNS N06617) is a solid solution strengthened superalloy of Ni, Cr, Co and Mo. Owing to the unique metallurgical composition, Alloy 617 has great resistance to high temperature corrosion in various environments and has been developed for high temperature applications above 800 °C. Therefore, it is often considered as a candidate for applications in gas turbines and power generation structures, heat exchangers, chemical manufacturing components and metallurgical processing facilities [1]. In these cases, there are components which work under high pressure and temperature and consequently are susceptible to creep and also simultaneous hot corrosion due to the usage of low grade fossil fuels. Singh et al. [2] has carried out a comprehensive review and reported that some fuels such as coal and fuel oil, due to their impurities (e.g. Na, S and V), deposit an alkaline metal salt layer on hot components during combustion, which is corrosive and results in hot corrosion of the substrate.

Hot corrosion and creep have synergistic effects on each other, and their interaction leads to the premature failure of alloys [2,3]. These two destructive phenomena have been investigated separately in several studies, but usually without taking their interaction into consideration. In order to study the interaction of hot corrosion and creep experimentally creep specimens are either coated with a salt deposit, as done by Ref. [4–6], or exposed to corrosive atmosphere, as tested by Ref. [7]. Lin et al. [4] investigated the creep behavior of Alloy GH-37 coated with Na_2SO_4 − 25 wt.% NaCl at 700 and 850 °C. They observed that hot corrosion decreases the creep life and fracture ductility of the alloy. Likewise, Suryanarayanan et al. [5] tested 304 stainless steel in the temperature range of 600–700 °C and reported that the eutectic liquid phase Ni-Ni_3S_2 formed in salt penetrated into grain boundaries and reduced the creep life. Yoshiba [6] coated Alloy 751 with Na_2SO_4 − 10 wt.% NaCl and conducted the creep tests at 800 °C with controlling the oxygen partial pressure. He remarked that creep forms micro-channels in the oxide scale and grain boundaries through which the molten salt directly penetrated along grain boundaries.

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Table 1
Chemical composition of Alloy 617 used in the study.

Element	C	Mn	Fe	Si	Cu	Cr	Ni	Al	Ti	Co	Mo	V	Nb	Zr	W	S
wt.%	0.07	0.08	1.5	0.15	0.06	21.48	54.43	1.2	0.4	11.8	8.6	0.01	0.08	0.01	0.12	Trace

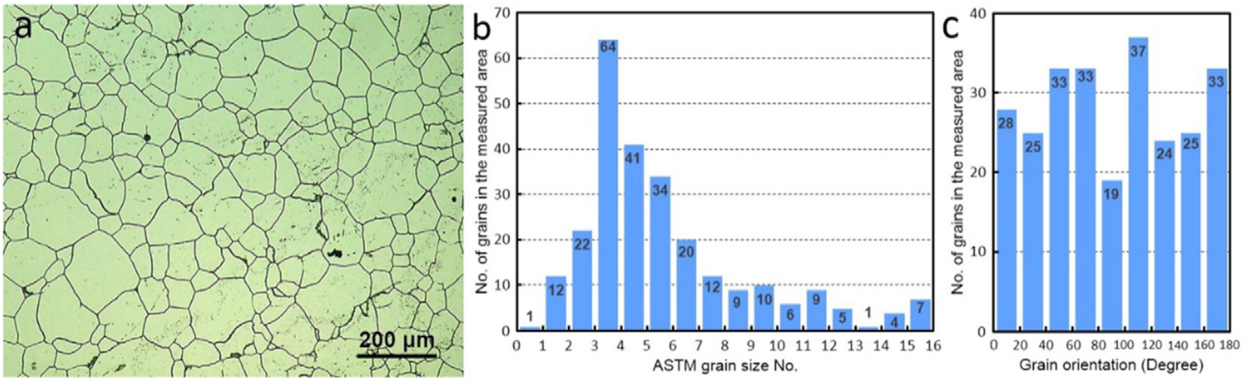

Fig. 1. As-received Alloy 617: (a) optical micrograph of the microstructure, (b) grain size distribution and (c) grain orientation in a (the measured area).

Combustion chambers of gas turbines work at high pressure and high temperature gas flow containing corrosive species and are consequently exposed to simultaneous hot corrosion and creep. Furthermore, combustion chamber walls are usually thin, which according to the result of Roy et al. [8] makes oxidation-creep interaction more effective. In the present work, an unused combustion chamber made of hot-rolled Alloy 617 sheet was selected as a sample to study the interaction. The purpose of this research is to evaluate the behavior of Alloy 617 under simultaneous hot corrosion and creep and to characterize the interaction mechanisms. This can provide a clear understanding of the failure under hot corrosion and creep and leads us into the solutions and also more accurate service-life prediction, matters of controversy in high-temperature applications.

2. Experimental procedure

The chemical composition of the sample sheet is given in Table 1.

Fig. 1a shows the microstructure of the as-received alloy. The grain size distribution in Fig. 1a, given in Fig. 1b, was measured according to ASTM E112-96. The corresponding grain orientation given in Fig. 1c shows that the grains were randomly oriented.

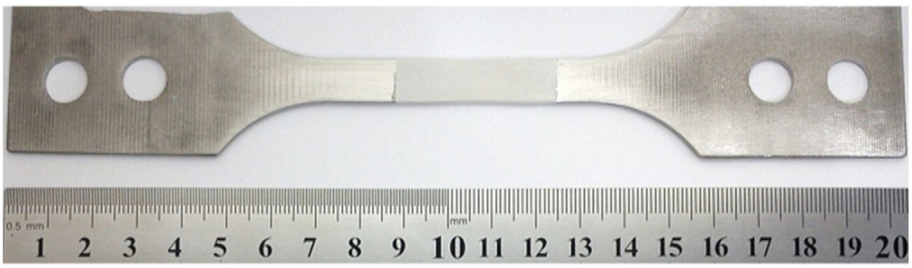

Fig. 2. The salt-coated creep specimen.

Table 2
Specimen IDs and the initial applied stress in creep tests.

Stress (MPa)	85	105	125
Salt coated	C1	C2	C3
Non coated	N1	N2	N3