Vacuum 109 (2014) 157–161

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum

Rapid communication

Influence of post ageing on creep behaviour of aluminized Ni-based single crystal superalloy prepared by low-activity high-temperature

F.H. Latief*, K. Kakehi

Department of Mechanical Engineering, Tokyo Metropolitan University, 1-1 Minami-osawa, Hachioji-shi, Tokyo 192-0397, Japan

ARTICLE INFO

Article history:
Received 28 May 2014
Received in revised form
23 June 2014
Accepted 5 July 2014
Available online 17 July 2014

Keywords:
Ni-based superalloys
Ageing
Creep
Coatings
Microstructure

ABSTRACT

The influence of post ageing treatment on creep behaviour of aluminide coating prepared by low-activity high-temperature on a Ni-based single crystal superalloy was investigated. The results showed that the aluminide coating reduced the creep behaviour of Ni-based single crystal superalloy. The decrease in creep behaviour may be due to the change in microstructures after aluminizing treatment. However, the post ageing treatment at low temperature has successfully improved the creep behaviour of aluminized Ni-based single crystal superalloy. The increase in creep behaviour of aluminized Ni-based single crystal superalloy after post ageing treatment was due to the formation of fine spherical carbides which are distributed in the substrate of Ni-based single crystal superalloy. These fine spherical carbides are able to hinder the dislocation movement and suppress the amount of topologically close-packed phase.
© 2014 Elsevier Ltd. All rights reserved.

Ni-based single crystal superalloys have been used extensively in the gas turbine components which are required to possess high temperature strength, good oxidation and corrosion resistance. Their great mechanical properties at high temperature are primarily related to the strengthening effect by the γ' precipitate [1]. Sometimes C, B, Hf and Zr are four elements employed to enhance grain boundary strength. These elements can modify matrix properties by forming second phases and adjusting partitioning of elements on solidification. The refractory elements such as Re, W and Mo have been added to improve the high temperature strength of Ni-based single crystal superalloys via solid solution hardening method [2].

A protective coating is therefore required to protect the surface of turbine blades used in engine hot sections. Aluminide diffusion coatings are widely used for high temperature oxidation and hot corrosion protection in the gas turbine components [3]. The most interesting method used in industrial sector to apply these aluminide diffusion coatings on Ni-base single crystal superalloys is called as pack aluminizing process [4]. Pack aluminizing is a method frequently used to apply protective coatings on the metal surfaces in order to prevent them from high temperature oxidation and corrosion damage. This method is not expensive and it can be applied on substrate with different heights and shapes.

Pack aluminizing process is fundamentally an “in situ” chemical vapour deposition coating process. The components are positioned in a sealed container together with the powder mixtures which consists of metal elements (such as aluminium and chromium), halide activators (such as NH_4Cl and NH_4F) and inert filler (regularly alumina). The components are embedded in the powder mixtures. The sealed container is then subjected to the vacuum furnace under an argon atmosphere and generally heated at a temperature between 700 and 1150 °C for a specified holding time [5]. Moreover, pack aluminizing process can be classified into two categories, namely low-activity high-temperature (LAHT) [6] and high-activity low-temperature (HALT) [7]. This classification is assigned with reference to the temperature of pack cementation process and the activity of the pack used. The LAHT is a single step aluminizing process which is usually carried out above 1000 °C. On the other hand, the HALT is a two-step aluminizing process which is normally conducted in the range temperature 700–850 °C and subsequent heat treatment which is usually performed above 1000 °C [3].

In the present study, we used the LAHT process to prepare the aluminide coating on a Ni-based single crystal superalloy. It is well-known that LAHT is a single step aluminizing process. So far, there has been no report that confirms the effect of post ageing treatment after a single step aluminizing process. Hence, the subsequent heat treatment that is post ageing was carried out after aluminizing treatment at the same temperature of secondary ageing of Ni-based single crystal superalloy. The aim of this study is therefore to

* Corresponding author. Tel./fax: +81 42 6772709.
E-mail address: fahamsyah78@gmail.com (F.H. Latief).

http://dx.doi.org/10.1016/j.vacuum.2014.07.003
0042-207X/© 2014 Elsevier Ltd. All rights reserved.

investigate the influence of post ageing on creep behaviour of coated single crystal Ni-based superalloy.

A Ni-based single crystal superalloy with a composition of 5.74 Al, 0.73 Ti, 0.5 Mo, 6 Cr, 9.3 Co, 1.4 Hf, 3.4 Ta, 2.9 Re, 8.3 W, 0.005 Zr, 0.016 B, 0.019 Fe, 0.07 C and balance Ni (mass %) was used as an experimental material. The Ni-based single crystal superalloy was solution heat treated at 1274 °C for 8 h under argon environment and subsequent by a two-step ageing treatment performed by primary ageing of 4 h at 1080 °C and secondary ageing of 20 h at 871 °C, both ageing treatments followed by air cooling to room temperature. The surface orientation of the specimens was determined by Laue back-reflection technique. The creep specimens were prepared by electric discharge machining along [100] orientation with a cross-sectional area of 2.8 mm × 2.8 mm and the gauge length of 19.6 mm (Fig. 1). The stress orientation of all specimens was within 4° of <001>. The specimens were mechanically polished down to 1200 mesh by emery paper and ultrasonically cleaned in acetone bath for 10 min prior to aluminizing process.

In this study, the LAHT process was used to prepare an aluminide coating with a mixture of 24.5 mass% Al, 24.5 mass% Cr, 49 mass% Al_2O_3 and 2 mass% NH_4Cl powders. The specimens were embedded in an Al_2O_3 container containing a mixture powders. The container was then set up in the furnace until a vacuum condition of 1×10^{-4} mPa and heated at 1000 °C for 5 h in flowing argon. After completion of aluminizing process, the coated specimens were post aged at the same temperature as secondary ageing condition that is 871 °C for 20 h. Post ageing treatment was conducted. Furthermore, the aluminized specimen with post ageing treatment designated as “CPAT”, whereas the aluminized specimen without post ageing treatment designated as “C”. The creep tests were carried out at 900 °C/320 MPa with a parallel load direction to <001> direction for all specimens. Additional creep test was conducted by examining the bare specimen at the same condition as the aluminized specimens in order to realize the effect of aluminizing treatment on the creep rupture life of Ni-based single crystal superalloy. The cross-section microstructures of as-aluminized and ruptured aluminized specimens were observed by scanning electron microscopy (SEM) equipped with energy dispersive spectroscopy (EDS). Microhardness measurements were applied on the coating-to-the substrate regions with a load of 100 g and 20 s and they were then averaged. The hardness measurement was carried out in order to evaluate the gradient of hardness on the coating-to-the substrate regions before and after creep tests.

Fig. 2 shows the SEM micrographs of specimen C and the specimen CPAT after aluminizing treatment. Three distinctive regions were obvious both in specimen C and specimen CPAT: (i) an outer protective layer (coating layer), an interdiffusion zone (IDZ) and the substrate. The IDZ was formed between the coating layer

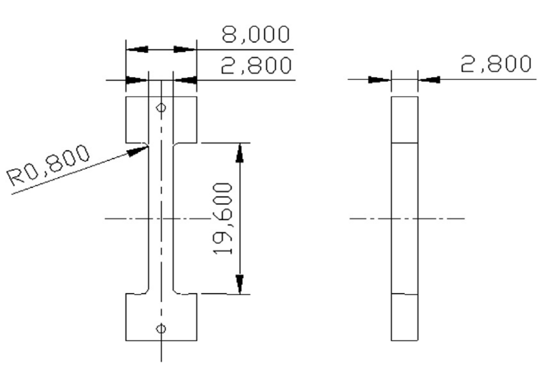

Fig. 1. Schematic of creep test specimens (mm).

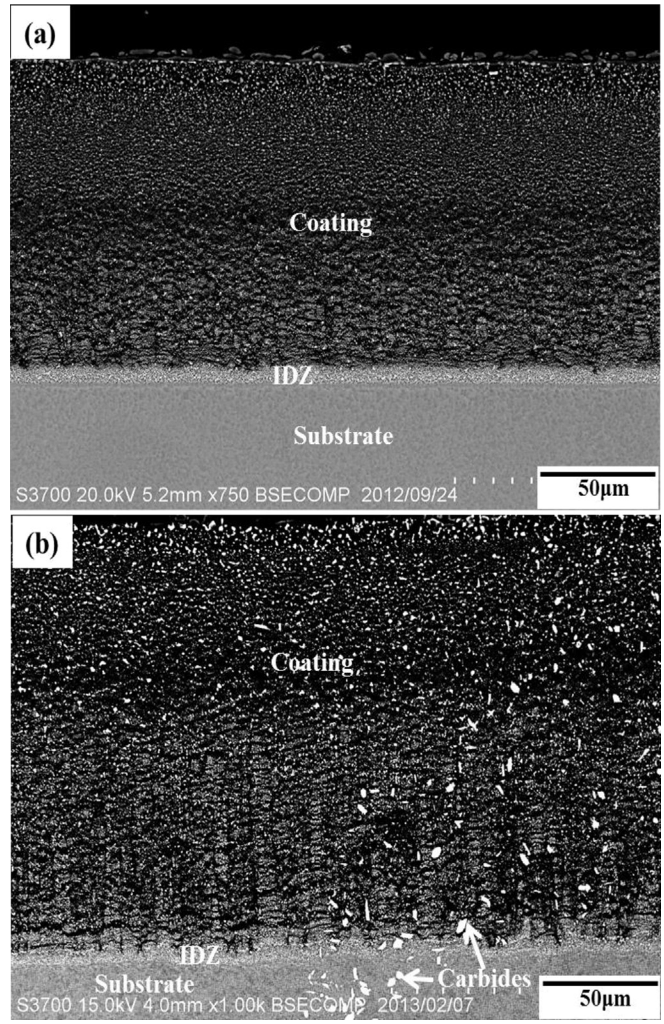

Fig. 2. SEM micrographs of as-aluminized microstructure for: (a) specimen C and (b). specimen CPAT.

and the substrate after aluminizing process and this is typical of LAHT process. The IDZ thickness of specimen C was about 3.5 μm (Fig. 2(a)). In Fig. 2(b), the IDZ thickness of specimen CPAT was about 3.1 μm. In addition, Fig. 2(b) contains more carbide compared to Fig. 2(a). It is evidence that the post ageing treatment lead to the formation of carbides with various shapes as seen in Fig. 2(b).

The creep behaviour results of bare and aluminized specimens are shown in Fig. 3. It is obvious that the bare specimen showed the highest creep strength compared to both aluminized specimens. From these results can be denoted that the aluminide coating presents a detrimental effect to the creep behaviour of Ni-based single crystal superalloy. The creep behaviour of bare specimen was 480 h. Meanwhile, the creep rupture lives of specimen C and specimen CPAT were about 308 h and 424 h, respectively. The decrease ration in creep rupture life of Ni-based single crystal superalloy caused by the aluminizing process was about 36%. On the other hand, the post ageing treatment has successfully enhanced the creep behaviour of aluminized specimen. The creep behaviour of specimen CPAT increased eminently and its increment was about 38% in comparison with the specimen C. In addition, the specimen CPAT showed a better elongation than that of the specimen C. Concisely, the post ageing treatment was an effective method to improve the creep strength of coated specimen.

Download English Version:

https://daneshyari.com/en/article/1688460

Download Persian Version:

https://daneshyari.com/article/1688460

Daneshyari.com