Creep Behavior and Microstructure of Nickel-Base Single Crystal Super alloy

Rajendra Kumar Nishad
Student
Department of Mechanical Engineering
Kirodimal Institute of Technology Raigarh (C.G.) INDIA

Tarun Kumar Painkra
Student
Department of Mechanical Engineering
Kirodimal Institute of Technology Raigarh (C.G.) INDIA

Kheer Sagar Naik
Student
Department of Mechanical Engineering
Kirodimal Institute of Technology Raigarh (C.G.) INDIA

Shailendra Kumar Bohidar
Faculty
Department of Mechanical Engineering
Kirodimal Institute of Technology Raigarh (C.G.) INDIA

Prakash Kumar Sen
Faculty
Department of Mechanical Engineering
Kirodimal Institute of Technology Raigarh (C.G.) INDIA

Abstract

In this review paper, the creep behavior of Nickel-base single crystal superalloy is studied, the aim of the study is creep behavior of Nickel-base single crystal superalloy, there are two different type of creep behavior can be shown in the creep curve. The primary creep is characterized by the high amplitude at test conditions of (760˚C, 600 M Pa) and (850˚C, 550M Pa) the primary creep strain is limited at (980˚C, 250 M Pa) (1100˚C 140M Pa) and (1120˚C, 120M Pa). The microstructure evolution of γ phase, TPC phase and dislocation characteristic after creep rupture was studied by SEM and TPC. The γ/γ microstructure of crystals in the BSE image, the bright area is γ matrix and the dark area is the γ′ phase.
Keywords: Creep behavior, Sueralloy, Single Cristal, γ/γ′microstructure

I. INTRODUCTION

Nickel-base super alloy single crystals have superior mechanical properties at elevated temperature, which make them the most suitable material for the manufacture of turbine blades in aero engine [1-4]. The purpose of the investigation is promoting the development of new generation single crystal super alloy with high creep properties [5]. The single crystal super alloy with various composition display different creep behavior, Nickel-base single crystal superalloy after two step again were studied. First one are high amplitude of primary creep strain and second one are quite long. [6] which are compare cubical γ' precipitates, microstructure of the single crystal after standard heat treatment. Although a large amount of investigations have demonstrated the creep behavior of nickel based single crystal superalloys only at intermediate temperatures or at high temperature [6-9].

II. CREEP BEHAVIOR

The creep curves of the nickel-based single crystal superalloy at different test condition are shown in Fig.1. It is two different types of creep behavior can be shown by the creep curves.

- The first one is characterized by the high amplitude of primary creep strain At **(760˚C, 600 M Pa)** and **(850˚C, 550 M Pa).**
- The primary creep stage amplitude is dramatically smaller at(980˚C,250 M Pa),(1100˚C,140 M Pa) and (1120˚C,120 M Pa) [5]

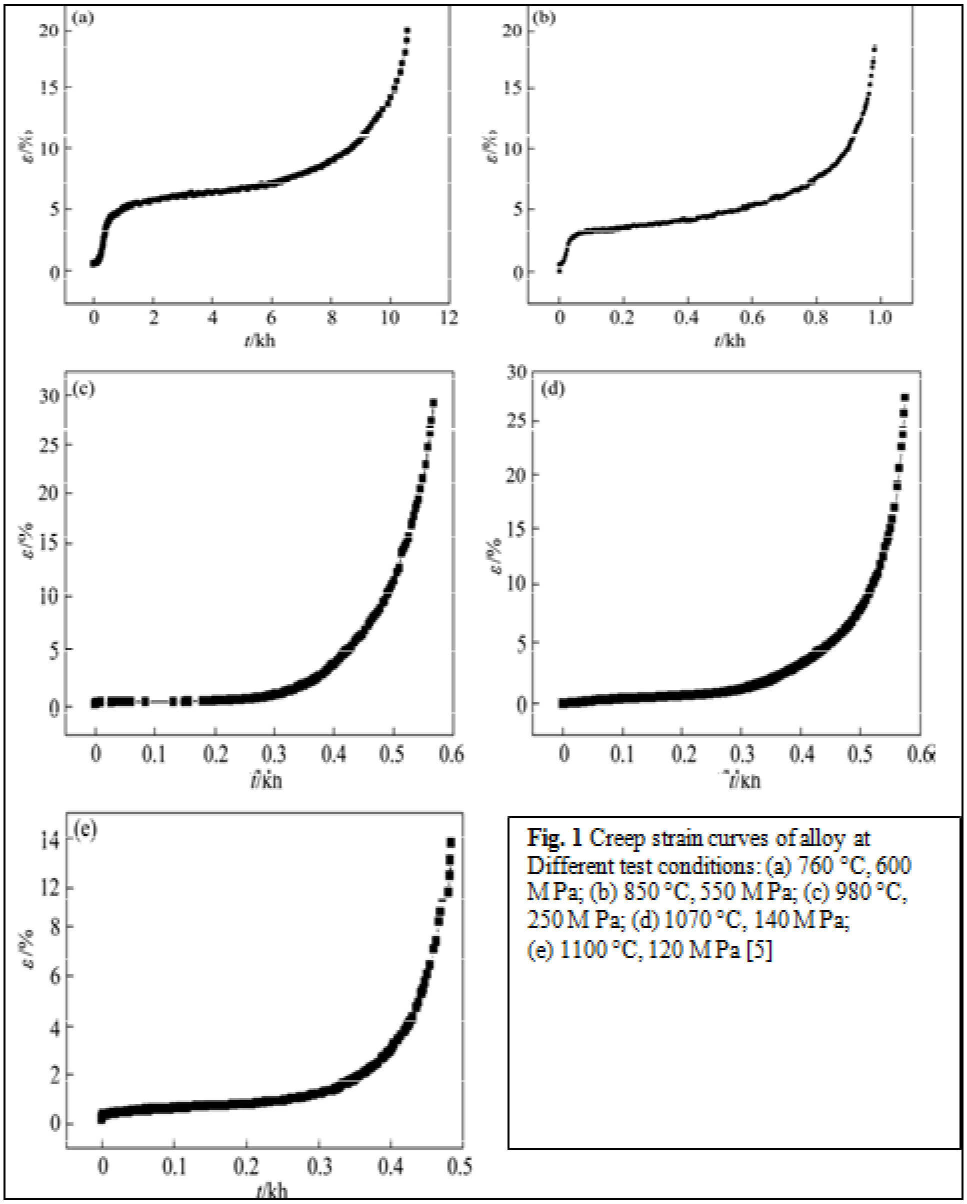

Fig. 1 Creep strain curves of alloy at Different test conditions: (a) 760 °C, 600 M Pa; (b) 850 °C, 550 M Pa; (c) 980 °C, 250 M Pa; (d) 1070 °C, 140 M Pa; (e) 1100 °C, 120 M Pa [5]

III. Γ/Γ′ MICROSTRUCTURE

The γ/γ′ microstructure in a Ni-based superalloy is similar to a composite material with two phases, γ and γ_. The γ-phase works as matrix and the L12-ordered γ_-precipitates as strengtheners [10]. Superalloys containing the L12-ordered γ_-precipitates surrounded by a γ-matrix, show better mechanical properties than either of the γ- or γ_-components themselves [11]. Figure.2 shows a typical Ni-based superalloy microstructure with the cuboidal γ_-precipitates surrounded by the γ-matrix.

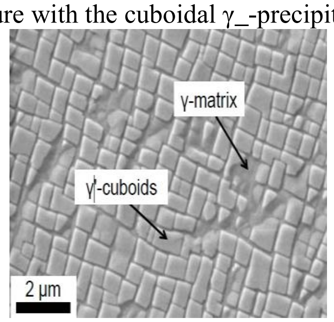

Fig 2: Scanning electron micrograph of typical Ni-based superalloy microstructure Cuboidal γ_-precipitates surrounded by a γ-matrix [11]

A. As grown γ/γ′ microstructure

The microstructures of the as-grown crystal are shown in Fig.3.The light gray areas are the dendrite cores (arrow B) and the darker areas (arrow C) are the interdendritic regions. The *γ*/*γ* microstructure in the dendrite cores Fig.3 (a) and in the interdendritic region Fig.3 (b) are almost the same.[8]

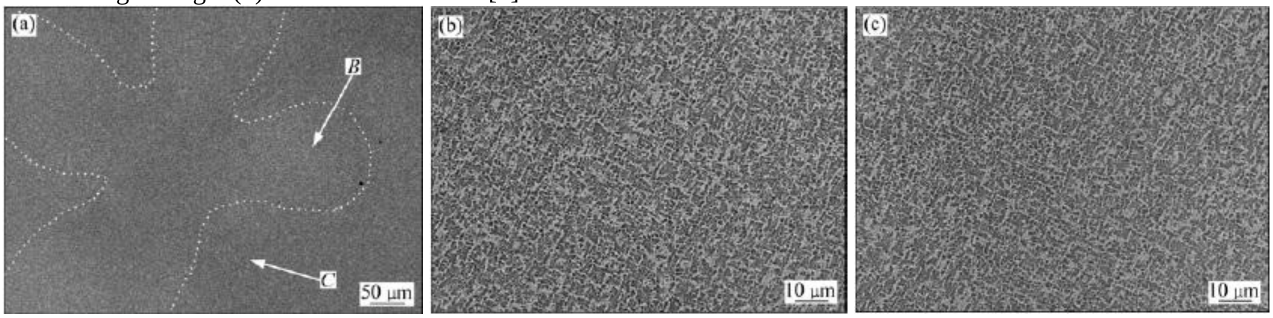

Fig.3 BSE micrographs of as-grown crystals: (a) Low magnification image showing weak dendrite pattern (boundary of dendrite is sketched by dotted lines); (b) *γ*/*γ*′ microstructure in dendrite cores; (c) *γ*/*γ*′ microstructure in interdendritic regions. [8]

B. microstructure after heat treatment

The microstructure of the single crystal superalloy after standard heat treatment. It can be seen that the primary γ and γ/γ' eutectic dissolve after high temperature solution treatment. The cubical γ' phase is arranged along {100} direction (Fig.4). [8]

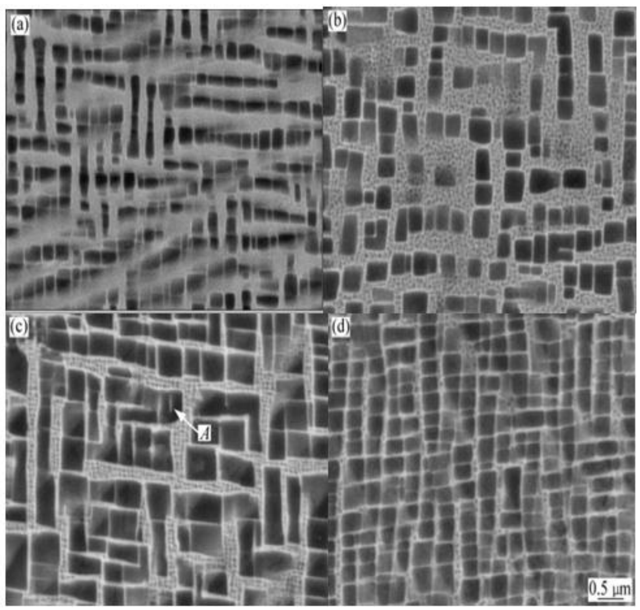

Fig 4 BSE micrographs of *γ*/*γ*′ microstructures after the first-step (a) and the second-step aging for 25 h (b), 35 h (c) and 40 h (d)(Bright area is *γ* matrix and dark area is *γ*′ phase)[8]

IV. CONCLUSIONS

(1) The size of the cuboidal *γ*′ precipitates' first increase and the decrease with the extension of the second-step aging time.
(2) Two different types of creep behavior can be shown in the creep curves. The primary creep was characterized by high amplitude at (760 °C, 600 M Pa) and (850 °C, 550 M Pa), and the primary creep strain is limited at test conditions of (980 °C, 250 M Pa), (1100 °C, 140 M Pa) and (1120 °C, 120 M Pa).
(3) The as-grown microstructures of the crystal are rather uniform; both cuboidal and spherical *γ*′ precipitates are formed after a two stage aging.
(4) The size of the cuboidal *γ*′ precipitates first increases and then decreases with the extension of the Second step aging time.

REFERENCE

[1] WALSTON W S, O′HARA K, ROSS E W, POLLOCK T M, MURPHY W H. RenéN6: Third generation single crystal superalloy [C]//KISSINGER R D, DEYE D J, ANTON D L, CETEL A D, NATHAL M V, POLLOCK, T M, WOODFORD D A. Superalloys. Warrendale: TMS, 1996: 27−34.
[2] ERICKSON G L. The development and application of CMSX-10 [C]//KISSINGER R D, DEYE D J, ANTON D L, CETEL A D, NATHAL M V, POLLOCK, T M, WOODFORD D A. Superalloys. Warrendale: TMS, 1996: 35−44.

[3] ARGENCE D, VERNAULT C, DESVALLEES Y, FOURNIER D. MC-NG: Generation single crystal superalloy for future aeronautical turbine blades and vanes [C]//POLLOCK T M. Superalloys. Warrendale: TMS, 2000: 829−837.
[4] WALSTON S, CETEL A, MACKAY R, O′HARA K, DUHL D, DRESHFIELD R. Joint development of a fourth generation single crystal superalloy [C]//GREEN K A, POLLOK T M, HARADA H,HOWSON T W, REED R C, SCHIRRA J J, WALSTON S. Superalloys. Pennsylvania: TMS, 2004: 15−24
[5] ZHEN-XUE SHI, JAI-RONG LI, SHI-ZONE LIU, XIAO-GUNG WANG Creep properties and microstructure evolution of nickel-based single crystal superalloy at different conditions : China, 24(2014) 2536−2543
[6] TIAN S G, ZHENG Z, LIANG F S, CHAO Z, CHEN L. Creep behavior of a 4.5%-Re single crystal nickel-based superalloy at intermediate temperatures [J]. Materials Science and Engineering A, 2012, 543: 104−109.
[7] YU X F, DU H Q, TIAN S G, NING Y, WANG T J, CUI S. Creep deformation mechanism in Re free second generation nickel-base single crystal superalloy during medium temperature and high stress [J]. The Chinese Journal of Nonferrous Metals, 2012, 21(7): 1921−1928. (in Chinese)
[8] FUCHS G E. Solution heat treatment response of a third generation single crystal Ni-base superalloy [J]. Materials Science and Engineering A, 2001, 300(1−2): 52−60.
[9] TIAN S G, ZHANG J H, ZHOU H H, YANG H C, XU Y B, HU Z Q. Aspects of primary creep of a single crystal nickel-base superalloy [J]. Materials Science and Engineering A, 1999, 262: 271−278.
[10] R. C. REED, *the Superalloys - Fundamentals and Applications*. Cambridge: Cambridge University Press, 2006.
[11] F. R. N. NABARRO and H. L. DE VILLIERS, *The physics of Creep – Creep and Creep-resistant Alloys*. 1st ed. 1995.