Investigation on the dissolution of \( \eta \) phase in a cast Ni-based superalloy

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(Received: 8 December 2011; revised: 19 January 2012; accepted: 7 March 2012)

Abstract: The dissolution behavior of \( \eta \) phase has been investigated in a cast Ni-based superalloy. The results showed that the platelets and blocks of \( \eta \) phase were formed within the interdendritic regions of the microstructure. Applying standard solution annealing at 1150-1160\(^\circ\)C for a period of 4 h did not result in the complete dissolution of \( \eta \) phase. For the complete dissolution of \( \eta \) phase without residual incipient melting, a 2-step solution annealing has been recommended. After dissolution at high temperatures, the \( \eta \) phase transforms to two MC-type carbides: one is enriched in Ti, Nb, and Ta, and the other is of (Zr,Ti)C type.

Keywords: superalloys; nickel alloys; phase transitions; dissolution; heat treatment; carbides

1. Introduction

IN939 is one of the relatively new developed cast superalloys designed for long lifetime and high resistance to corrosion at temperatures up to about 850\(^\circ\)C. This alloy has been developed for manufacturing gas turbine blades and vanes [1-2].

In order to provide appropriate creep properties at temperatures higher than 800\(^\circ\)C, the alloy is usually subjected to four stages of heat treatment known as “standard four-stage heat treatment”. The four stages of this heat treatment are as follows [1-2]:

1160\(^\circ\)C (4 h)/FAC+1000\(^\circ\)C (6 h)/
FAC+900\(^\circ\)C (24 h)/AC+700\(^\circ\)C (16 h)/AC,
where FAC is fast air cooling and AC is air cooling.

Other heat treatment procedures have also been presented in Refs. [3-5]. These publications refer to a solution annealing cycle in the temperature range of 1150-1160\(^\circ\)C for 4 h. The aim of applying this type of solution annealing cycle is said to be the full solution of \( \gamma' \) and \( \eta \) phases in the microstructure of the cast alloy and homogenization of the material to optimize its mechanical properties [1, 6].

Up to now, there is no any published report on either the precise composition and morphology of \( \eta \) phase or the dissolution behavior of this phase in IN939 alloy. Ref. [7] has mentioned that, for IN792 + Hf castings, \( \eta \) phase has a stable constituent and cannot be removed by solutioning at temperatures below the incipient melting point of the alloy via heat treatment. Wang et al. [8] have reported the formation of some \( \eta \) phases during the solidification of Waspaloy at 1300\(^\circ\)C. Recently, Xu et al. [9] have shown that \( \eta \) phase could be formed in Udinet 710 superalloy having high Ti and Co contents at 1200-1220\(^\circ\)C. On the other hand, in accordance with some other literatures [10-11], the solution temperature of \( \eta \) phase is in the range of 1175-1190\(^\circ\)C in some similar superalloys. Therefore, the reported solution temperature of 1145\(^\circ\)C for \( \eta \) phase in IN939 superalloy [1, 6] is questionable and it will be useful to investigate the dissolution behavior of \( \eta \) phase in a systematic study.

Because of the need for homogenization of the microstructure via full dissolution of \( \eta \) phase and also the