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Short Communication

Effect of overheating temperature on the microstructure and creep behavior of HP40Nb alloy

W.Z. Wang *, F.Z. Xuan, Z.D. Wang, B. Wang, C.J. Liu

Key Lab of Safety Science of Pressurized System, Ministry of Education, School of Mechanical and Power Engineering, East China University of Science and Technology, Shanghai 200237, PR China

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ABSTRACT

HP40Nb alloy has been widely used as a high temperature material in petrochemical plants. However, overheating or local temperature excursion occurs occasionally in service and leads to serious damage on the material. Effect of temperature on the microstructure and creep performance of the HP40Nb alloy is investigated in the present work. Several specimens are cut from serviced components of the alloy and heat-treated at different temperatures from 900 °C to 1250 °C for its possible working conditions, in which the temperature of 1200 or 1250 °C is used to simulate the overheating condition of HP40Nb tubes. The microstructure of specimens is examined by scanning electron microscope (SEM) and transmission electron microscope (TEM). The creep behavior is evaluated through using impression creep tests with a flat-ended cylindrical indenter. The content of inter- and intra-dendritic carbides in the specimens is represented by the surface fraction of each phase, which has been estimated by image processing method. The results show that the total of the surface fraction of inter- and intra-dendritic carbides in the HP40Nb alloy does not significantly change at the temperature lower than 1100 °C. However, the surface fraction of inter-dendritic carbides reaches the maximum at 1100 °C. A maximal steady state impression rate is also observed at 1100 °C. The results suggest that the content of inter-dendritic carbides is the main influencing factor on the creep performance of HP40Nb alloys comparing with that of the intra-dendritic carbides.

1. Introduction

HP40Nb alloy has high creep resistance, favorable high temperature properties and good corrosion resistance in oxygen and carbon enriched circumstances. Centrifugally cast HP40Nb alloys are widely used to make high temperature components in petrochemical systems, e.g. as reformer tubes, radiation tubes and cracking tubes etc. The finite life of the components is correlated closely to some known or foreseeable damage mechanisms such as creep, fatigue, erosion or corrosion. Correspondingly, it should be designed properly in order to ensure the safe operation of equipments. However, the design life is not expected to be equal to the actual life, as the true service conditions or the actual material and component performance are not exactly known at the time of design [1]. Overheating or local temperature excursion [2,3] occasionally occurs for improper operation or formed coke influence. High temperature operation for a prolonged duration leads to serious damage in structural components, due to the occurrence of temperature sensitive plastic deformation and surface degradation processes [4].

Creep is recognized to be a main mechanical loading condition leading to the failure of HP40Nb tubes [5]. Over the past several decades, researchers have paid more attention to the creep damage evaluation [6–8] and the remaining life assessment [9] of the components. However, there is almost no investigation found on the effect of working temperature on the microstructure and creep performance of HP40Nb alloys, especially when they suffer overheating or local temperature excursion. In addition, conventional creep testing requires many samples and therefore is time consuming and inconvenient. On the contrary, impression creep test is attractive for its quickness and reliability to determine the creep behavior of materials. During impression creep tests, only a small quantity of testing material is required [10]. Furthermore, absence of tertiary stage of creep in impression creep tests makes the deformation more stable [10]. It was found that a steady state impression velocity at a constant load can be achieved under a cylindrical indenter with a flat bottom [11]. Up to now, this test has been applied to a number of metals and alloys, e.g. titanium alloy [12], Al, Cu and mild steel etc. [13]. The impression creep behavior of ceramics, such as magnesia-silica glass [14] and $MoSi_2$–SiC composites [15], has also been investigated by this method. Under certain conditions, compressive creep and impression creep measurements yield comparable results after correcting for effective stresses and strain rates beneath the indenter.

* Corresponding author. Tel.: +86 21 64252819; fax: +86 21 64253513.
E-mail address: wangwz@ecust.edu.cn (W.Z. Wang).

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Table 1
Chemical composition of as-cast HP40Nb tube.

C	Mn	Si	S	P	Mo	Cr	Ni	Nb
0.38–0.45	0.50–1.50	0.50–1.50	0.03	0.03	0.50	24.0–27.0	34.0–37.0	0.6–1.25

Therefore, the technology of impression creep test is adopted in the present work to obtain the creep behavior of the HP40Nb alloy after working at different temperatures.

The purpose of this work is to examine the microstructure and evaluate the degree of creep damage of the HP40Nb alloy after working at different temperatures, to improve the understanding

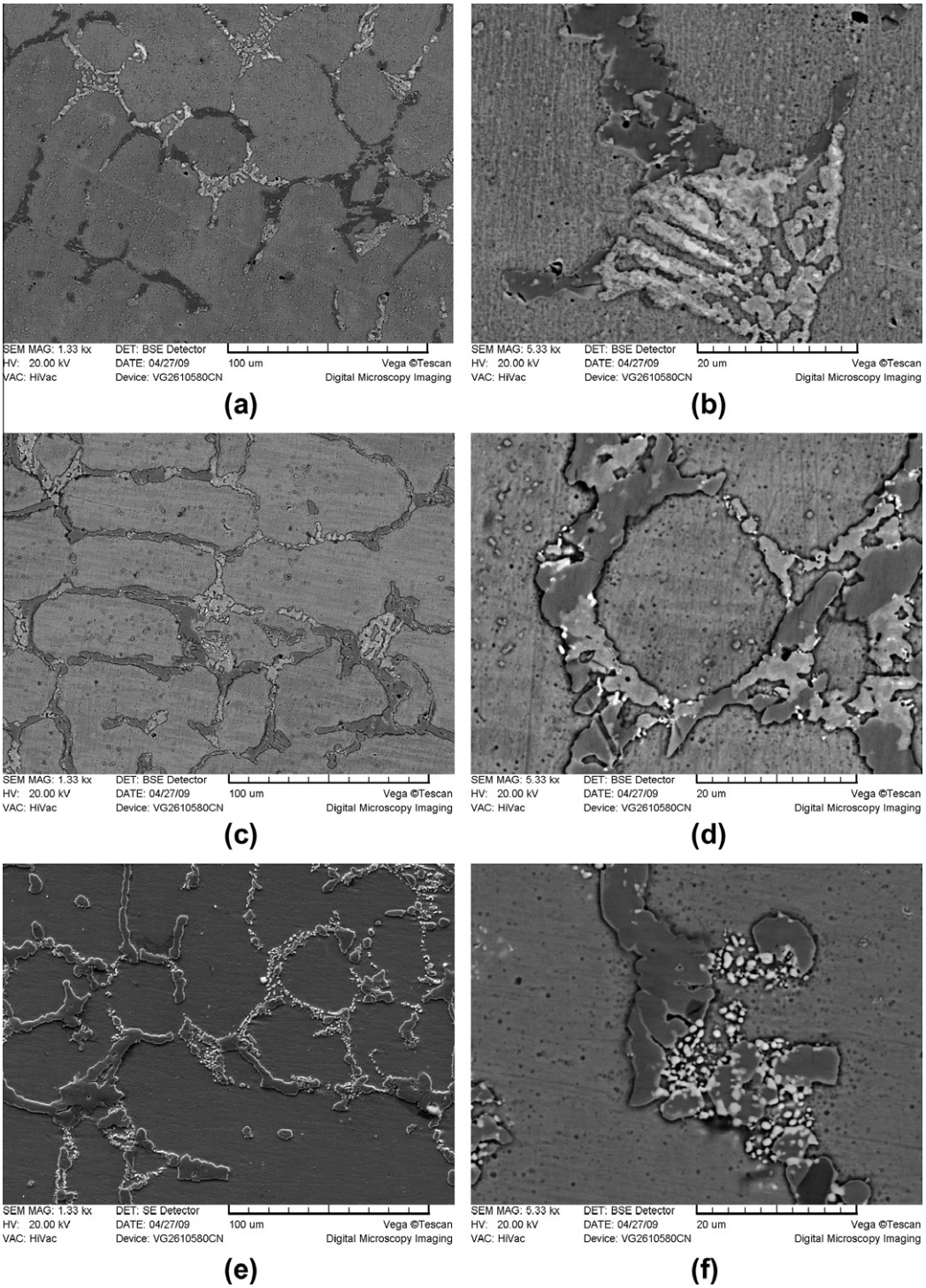

Fig. 1. Microstructure of the HP40Nb alloy after heat-treated at 900 °C (a and b), 1000 °C (c and d), 1100 °C (e and f), 1200 °C (g and h) and 1250 °C (i and j) for 100 h.