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# Aging of a Low Carbon Heat Resistant Cast Alloy

DOI 10.1515/htmp-2016-0112
Received June 13, 2016; accepted December 30, 2016

**Abstract:** The changes in microstructure that take place during aging a low carbon heat resistant alloy at 750°C for a period of time of up to 1,000 h were studied by optical and scanning electron microscopy, X-ray diffraction and mechanical testing. The microstructure of the as-cast alloy consisted of an austenitic matrix and a network of Nb- and Cr-rich primary carbides that were identified by their tonality when viewed in backscattered mode in a scanning electron microscopy. Aging promotes precipitation of secondary carbides and the transformation of the Nb-rich particles. The mechanical properties are affected by the occurrence of the different phenomena.

**Keywords:** heat-resisting cast alloys, precipitation, aging, microstructural evolution

## Introduction

Heat-resistant alloys are used in environments subjected to oxidizing or corrosive atmospheres at temperatures above 650 °C. Their main constituents are nickel, chromium and iron, and contain different amounts of niobium, titanium, vanadium and zirconium to enhance their creep resistance by the formation of particles stable at the operating temperatures. Their chemical compositions have changed through their use during the last 50 years; early alloys were cast conventional stainless steels (HB and HC types, 18Cr-4Ni and 18Cr-8Ni), that turned into HK (25Cr-20Ni) and HP (25Cr-35Ni) types. The purpose for the reduction in fuel consumption and in emissions impose harsher operating conditions in many industrial sectors, and so the new heat resistant alloys contain reduced amounts of carbon and higher amounts of chromium and nickel, as well as and many other elements [1–12].

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## Experimental procedure

Samples from a heat resistant alloy (0.15 C, 16.8 Fe, 34.0 Cr, 1.53 Si, 1.31 Nb, 1.03 Mn, 0.08 P, 0.02 P, 0.01 S, bal. Ni, mass %) were cut from a centrifugal cast pipe of 1500 mm in length with internal and external diameters of 108 and 130 mm, respectively; cylindrical tensile specimens of 25 mm in length and 6.4 mm in diameter were machined with their axis parallel to that of the pipe. The tests were conducted at room temperature in material that was either in their as-cast and or aged conditions; Vickers microhardness tests (200 g for 15 s) were also conducted. The material was held at 750 °C for up to 1000 h in air in an electric resistance furnace. The samples were prepared for their metallographic examination following standard polishing procedures and were etched with an electrolytic solution of 10 g of oxalic acid in 100 ml of water. A potential of 6 V was applied for 3–5 s using a stainless steel cathode; the temperature of the etchant was kept at 26 °C.

The microstructure of specimens in the as-cast conditions and aged for 500 and 1000 h were examined in an inverted light optical microscope (LOM). A scanning electron microscope (SEM) was used to evaluate the microstructure of selected samples using secondary (SE) and backscattered electron (BE) detectors. X-ray analyses of selected areas were also obtained (EDX). The presence of different phases was identified by X-ray diffraction (XRD) using copper radiation ($\lambda = 0.15418$ nm) in the interval of 2θ of 20 to 100° with a time step 13 s and 2 θ of 0.02°.

## Results and discussion

Optical examination of the as-cast samples shows that the microstructure of the alloy is made of an austenite dendrite matrix, with a secondary dendrite arm spacing of 40 μm, and a network of primary eutectic carbides present in the interdendritic regions (Figure 1). Figure 2 shows images taken from the alloy using the detector for SE, Figure 2(a), and BE, Figure 2(b). The difference in tonality of the carbides can be appreciated, as heavier elements appear in lighter tones. Selected EDX analyses carried out on the matrix and on either type of carbide show that the bright particles contain niobium, whereas