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# Microstructural degradation of two cast heat resistant reformer tubes after long term service exposure

M. Mostafaei, M. Shamanian *, H. Purmohamad, M. Amini, A. Saatchi

*Department of Materials Engineering, Isfahan University of Technology, Isfahan 84156-83111, Iran*

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ABSTRACT

Microstructural evolution of a gas reformer tube made of the two dissimilar heat-resistant cast alloys, 25Cr–35Ni and 28Cr–48Ni–5W, was studied using light optical microscopy and scanning electron microscopy equipped with energy dispersive spectroscopy point analysis. Specimens were cut from an ex-service, failed reformer tube aged 8 years. The phases and carbides at each section of the reformer tube were determined and compared with as-cast conditions. It was found that the specimens located far from the bottom or the roof of the reformer box had mainly meta-stable phases such as G-phase or $M_{23}C_6$ due to exposure to intermediate temperatures. Those inside the reformer box, however, had phases such as $M_6C$ carbides which are more stable than $M_{23}C_6$, and NbC due to exposure to high temperatures above 1000 °C.



## 1. Introduction

Cast heat resistant steels are used in applications where service temperature exceeds 650 °C. These steels exhibit excellent creep strength, resistance to corrosion at elevated temperatures, and stability. The 25Cr–35Ni (HP) steel is a heat resistant alloy that has a combination of creep strength and resistance to oxidizing and carburizing atmospheres at high temperatures [1,2].

For service at temperatures above 1100 °C, certain proprietary alloys of the nickel–chromium–iron type have been developed. Such alloys contain tungsten to form tungsten carbides, which are more stable than chromium carbides at these high service temperatures [2]. The tungsten-bearing 28Cr–48Ni–5W (HV) alloy, a nonstandard heat resistant alloy, is typically considered for applications at high temperatures (1100–1200 °C) where small diameter and thin wall tubing is required. The alloy has additionally a higher stiffness at these temperatures, which minimizes bowing and distortion [3].

The Direct Reduction Unit at Mobarakeh Steel Company uses gas reformer tubes to handle and transport the gas reformed to reduce iron ore for producing sponge iron. These heat resistant alloy tubes made of HP and HV are joined according to the schematic view shown in Fig. 1. As per the manufacturer's recommendations, these tubes have an effective operating life of about 10–11 years; however, some have failed far sooner.

In the present work, the microstructural characterization of a failed reformer tube in service for 8 years is investigated. In addition, phase and carbide types at each section of the reformer tube are determined and compared with the as-cast microstructures. The main objective of the study is to gain an understanding of the microstructural changes in the exposed tubes positioned at different points of service. The findings will then be used to investigate the repair weldability of the alloys, a topic which will receive an in-depth investigation in our future research.

* Corresponding author. Tel./fax: +98 311 3915737.
*E-mail address:* shamanian@cc.iut.ac.ir (M. Shamanian).

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