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Analysis of failed electron beam welds in ethylene cracking tubes

Kaishu Guan *, Qiangqi Wang

The Key Laboratory of Safety Science of Pressurized System, Ministry of Education, East China University of Science and Technology, Shanghai 200237, China

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ABSTRACT

The occurrence of cracks at the electron beam (EB) welds of ethylene tubes in radiant chambers after 1–2 years in service has led to serious concerns. Failure analysis of the sample using optical microscopy, scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) clearly reveals a centerline with dendritic crystals and blocky precipitates present at the welds, where the cracks occurred. Niobium-depletion at the EB weld centerline is mainly responsible for the carbide precipitates and cracks. Operation processes such as frequent start–stop cycling accelerated the cracks.

1. Introduction

Cracking takes place at several electron beam (EB) welds of ethylene tubes in the 6–7 m portion of inlet tubes in the radiant chambers after 1–2 years service. The tubes made of HP40 steel are welded using the EB method. This alloy is a creep resistant austenitic steel with a predicted service life of 100,000 h at elevated temperatures [1]. The actual service life, however, varies from 30,000 to 180,000 h, depending on the service conditions and the quality of materials. Due to prolonged exposure to high temperature, the microstructure of the material is subject to degradation. Although, sufficient care is taken in selecting materials, in designing and in operations, failures can seldom be avoided for various reasons such as overheating [2,3], stress corrosion cracking [4], creep and fatigue [5–7]. Failure of the tubes after such a short operation time may lead to material loss and may result in consequences in safety. Therefore, the failure of EB welds becomes critical. It is of practical importance to be able to reveal the failure mechanism.

2. Background

The ethylene cracking tubes are installed vertically. The feed gases, such as naphtha and steam, enter at the top end at a pressure of 0.1 MPa and flow down into the individual tubes. The ethylene cracking reaction takes place in the tubes and is endothermic. The heat is transferred to the cracking tubes through radiation and the metal temperature is maintained between 700 °C and 900 °C as per design requirement. The chemical composition of the welds shown in Table 1 is in agreement with the requirements of the specifications for 25Cr35Ni–Nb metal which can withstand elevated temperature operations. The size of the tube is ϕ 64 mm × 6 mm.

Several ethylene cracking furnaces have been damaged after 1–2 years in service. The damage style or the rupture pattern observed in several tubes, is almost the same. All the cracks are circumferential at the EB weld centre as shown in Fig. 1. All

* Corresponding author.
E-mail address: guankaishu@ecust.edu.cn (K. Guan).

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