Engineering Failure Analysis 18 (2011) 2288–2295

Contents lists available at SciVerse ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Role of oxide notching and degraded alloy microstructure in remarkably premature failure of steam generator tubes

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ARTICLE INFO

Article history:
Received 13 January 2011
Received in revised form 6 August 2011
Accepted 27 August 2011
Available online 6 September 2011

Keywords:
Superheater tubes
Creep
Decarburization
Oxidation
Overheating

ABSTRACT

Failure analysis investigation was carried out on a ruptured primary superheater tube of a boiler unit in a power plant. The rupture of 1Cr–0.5Mo steel tube had caused steam leakage and led to boiler shutdown after only 17,520 h of operation. The physical and mechanical characteristics of the alloy and the oxide scales in the area of failure were characterized by visual inspection, optical microscopy and microhardness testing, whereas the chemical variations were examined by optical emission spectrometry and energy dispersive spectrometry (EDS). A distinct surface/sub-surface zone of decarburization that was observed both on the inner and outer sides of the tube was developed before the tubes were put to the service. The fracture was attributed to a prolonged overheating as a result of the oxide scale build-up, causing loss of creep strength. The decarburized surface/sub-surface facilitated crack initiation/propagation.

1. Introduction

Cr–Mo steels are used extensively for construction of boilers and superheaters tubes because of their desirable combination of corrosion and creep resistance. However, microstructure of Cr–Mo steels is very susceptible to thermal variations/treatments [1–4]. In fact, this thermal susceptibility of microstructure is often exploited to develop carbide precipitates of required chemistry, morphology and distribution for the purpose of precipitation hardening [1,4]. However, due to the metastable nature of the composition and morphology of the strengthening precipitates, these secondary precipitates could undergo undesirable transformations if subjected to heating at excessive temperatures, such as undue over-heating of the component during service or the thermomechanical treatments experienced during welding, forging, and hot-rolling. Such undesirable changes can drastically deteriorate the mechanical properties such as creep rupture life of these creep-resistant alloys.

A superheater is commonly employed in power plants steam generation system, for converting wet steam into dry steam for power generation and other processes. Superheaters in gas-fired plants consist of banks of tubes suspended in the combustion gas flow path in the upper parts of the boiler. The complexities of the prolonged exposure to high temperatures, stresses and aggressive environment often lead to eventual ruptures/failure of superheater tubes [5–7]. The ruptures are caused by overheating, oxidation, pitting, stress corrosion cracking, stress rupture, creep, erosion, and thermal fatigue [8]. Overheating has been found to be the most common cause, and it usually occurs due to inadequate cooling of the tubes or thickening of oxide scale as a result of localized oxidation/oxide notching; and thus, it subjects the tubes to temperatures

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doi:10.1016/j.engfailanal.2011.08.005