International Journal of Pressure Vessels and Piping 88 (2011) 34–44

Contents lists available at ScienceDirect

International Journal of Pressure Vessels and Piping

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

Crack initiation and crack growth assessment of a high pressure steam chest

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ARTICLE INFO

Article history:
Received 9 June 2009
Received in revised form
9 November 2010
Accepted 29 November 2010

Keywords:
Creep
Fatigue
Ductility
0.5%Cr–0.5%Mo–0.25%V
Steam chest

ABSTRACT

Extensive cracking had occurred in a number of high pressure steam chests. An assessment was undertaken based on the R5 British Energy methodology to assess the components for both creep–fatigue damage initiation and crack growth analysis to determine fitness for purpose. The analysis determined that the remaining base rupture endurance life of the component was greater then 1 million hours, however, due to the start-up and shutdown ramp rates, creep–fatigue damage greater then unity has occurred leading to crack initiation in a number of locations. These cracks were confirmed during internal inspection of the steam chest. A subsequent crack growth analysis determined that the component could safely be returned to service for the expected future life of the station.

1. Introduction

Steam chests or throttle valves are a major component in steam generating power utilities. Creep rupture and the accumulation of creep–fatigue damage over time is the principal damage mechanism which will eventually lead to crack initiation in many of these components due to the large wall thickness [1]. The primary cause of this creep–fatigue damage is thermal stress during start-ups and shutdowns or load shifts [1–3]. In general, the up-shock cycle tends to characterise the thermal loading for components such as main steam pipe work, steam chests, HP rotors, and headers upstream of attemporation. The down-shock cycle is observed in headers downstream of attemporation and components that form part of the feedwater system. Some high-temperature components can experience both types of cycles for example, the steam chest downstream of the stop valves where throttling takes place may experience a thermal quench [4]. Power stations, due to changes in demand and competition from cheaper energy sources and in the future from added carbon taxes are being subjected to two-shift operation [5]. Two shifting implies that the station will respond rapidly to load changes on the system, ensuring that the grid maintains specified frequency and voltage, this implies that as well as additional cycles on a plant, the ramp rates of the cycles tend to be faster to ensure adequate load following.

The utility inspected has eight HP Steam chests across four units they are all of original construction. Since their original installation, they have each undergone routine overhaul. The valves are forged from 0.5%Cr–0.5%Mo–0.25%V steel. Unlike larger units where the steam chest and the turbine stop valve are separate components, in this configuration they are manufactured from a single forging. Inspections have revealed significant cracking at the internal radii of the steam chest bodies on almost all steam chests. A remaining life assessment was undertaken of the steam chest, metallurgical assessment was followed by detailed stress analysis using finite element analysis. Both crack initiation and crack growth calculations were undertaken to determine the future operating life of the component. The crack initiation creep–fatigue damage calculated was based on the R5 methodology [6].

2. Metallurgical assessment

2.1. General

Replicas were taken from a number of internal locations of the steam chest. All structures revealed by the replicas, including the structures in the cracked areas, indicated that the original microstructure of the steam chests consisted of ferrite and bainite. The bainite content was estimated as being between 10 and 20% by volume in the steam chests. Thermal degradation of the structures at all locations in the steam chests had occurred. In most locations of the steam chests, spheroidisation of the carbides in the bainite was complete and the bainitic form was moderately degraded in

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0308-0161/$ – see front matter
doi:10.1016/j.ijpvp.2010.11.003