Case Studies in Engineering Failure Analysis 8 (2017) 36–48

Contents lists available at ScienceDirect

Case Studies in Engineering Failure Analysis

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

Short communication

Overheated pipe due to scale: Field failure investigation and finite element analysis

H. Sunandrio[a], H.A. Suhartono[a], Y. Prawoto[b,*]

[a] Technology Center for Strength of Structures, The Agency for the Assessment and Application of Technology, Building #220, Region Puspiptek Serpong, Banten, Indonesia

[b] Department of Mechanical Engineering, South Ural State University (National Research University), 76 Lenin Ave., Chelyabinsk, 454080, Russia

ARTICLE INFO

Keywords:
Fin tube coil
Failure analysis
Finite element analysis
Heat transfer analysis

ABSTRACT

Through a field failure investigation and finite element analysis, a study on overheated pipe due to scale was performed. The field failure samples were collected from primary reformer convection tube made of material based on ASTM A 335 grad P91 modified specification. The type of the object was a fin tube coil. The tube shows rupture with the shape of fish mouth accompanied by bulging. The analysis performed using finite element mimics the actual field conditions. It was discovered that long term overheating due to scale both at the outside and in the inside of the tube hinders the smooth heat transfer process. This consequently leads to poor heat transfer and violates the original design philosophy. Metallurgical evaluation proves this verdict. Furthermore, the finite element analysis also supports the conclusion.

1. Introduction

A fin convection tube of a primary reformer convection section exploded in a high pressure steam super heater coil, the flue gas inlet and outlet temperature is 356 °C and 492 °C and the pressure 123 kg/cm2 ≈ 12,1 Mpa. The outer diameter is 120 mm, with 11 mm thickness. Cases of failure in piping used in high temperature and high pressure are still reported even until recently [1–3]. Kaewkumsai reported the degradation of AISI 310 austenitic stainless steel pipe, which was used at high temperature in carbonaceous reducing atmosphere used various techniques including on-site investigation, optical microscopy, scanning electron microscopy, energy dispersive spectroscopy, X-ray diffraction, metallography, and micro-hardness measurement. He discovered that growth of carbide precipitates and disintegration of alloys into dusts of coke and particles suggested carburization and metal dusting failure. Chen uses finite element analysis (FEA) of cyclic accumulation of plastic deformation, occurs when the structures are subjected to a primary load with a secondary cyclic load if the applied loads are high enough to make the structures yield. Almost all researchers quoted here agreed that most of the causes were due to not sufficient maintenance.

Learning from Fukushima-nuclear power plant accident, Kasahara et al. [4,5] map out the possible failure modes which should be assumed for extreme loadings such as very high temperature, high pressure and great earthquakes. Failure modes of main components under design extension conditions according three categories of loading modes as combination of high temperature, internal pressure. and external pressure loading mode are investigated. Kasahara et al. [6] studied relations between failure modes and extreme loadings by the numerical simulation using the cylindrical model. Liang and Zhao [7] explore the failure of spiral finned tube on a newly designed and retrofitted low pressure economizer in a 300 MW pulverized-coal-fired power plant. In the works it were emphasized the important of understanding the failure mode and the loading in order to find out the cause of failures.

* Corresponding author.
E-mail address: yunan.prawoto@gmail.com (Y. Prawoto).

http://dx.doi.org/10.1016/j.csefa.2017.04.003
Received 6 March 2017; Received in revised form 14 April 2017; Accepted 24 April 2017
Available online 29 April 2017

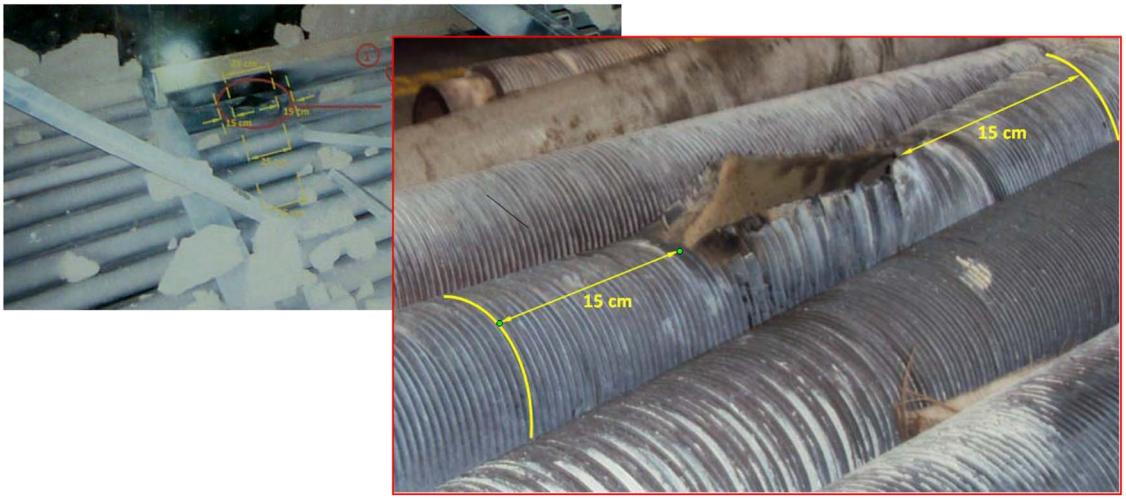

Fig. 1. Appearance of the failed sample within the system used.

It is true that engineers in the field often underestimate on the effect of the scale in damaging their equipments, especially the passive units such as piping. It is true that as parts of routine maintenance, cleaning the scale is mandatory to be performed yearly or every two years. However, the implementation in the field is not usually done too seriously. The effect of scales and deposits is often underestimated. The issue is typically considered less important than other issues and therefore less strict rule is being used as compared to other inspections such as corrosion or wall thinning of piping.

In this paper, we clarify that maintaining scale on the piping is as important as other subjects is. Through an investigation of the field failure instance and finite element analysis, a study on overheated pipe due to scale was performed. The field failure samples were collected from a fertilizer manufacturing company in Indonesia on August 2014. primary reformer convection tube, which has the material to meet ASTM A 335 grad P91 modified specification. The type of the tube was a fin tube coil. The tube shows rupture with the shape of fish mouth accompanied by bulging. The analysis was performed using finite element method to mimic the actual field conditions. Commercial code Abaqus™ was used to implement the modeling and analysis.

2. Methodology

The works consisted of some significant features. The background information is collected to recognize the operational conditions that might have caused the failures. The object of the study was chosen from several tube coils failed on the steam super heater. Since all the failed tubes exhibit similar failure appearances, only one tube was taken for detailed evaluation.

Subsequently the fractography based on ASTM E340, Metallography based on ASTM E407, and SEM/EDX of pipes was instigated on the segment and its adjacent failure area. The chemical composition analyses based on ASTM E751 is conducted to characterize

Fig. 2. Appearance of the failed sample evaluated in the lab.