Engineering Failure Analysis 77 (2017) 118–125

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Short Communication

Failure investigation of a cooling coil tube in zinc roaster furnace

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ARTICLE INFO

Article history:
Received 19 August 2016
Accepted 4 January 2017
Available online 01 March 2017

Keywords:
Galvanic corrosion
Localized corrosion
Cooling coils
Zinc oxide
Zinc roaster

ABSTRACT

The failure analysis of a cooling coil tube employed to extract the sensible heat of roasted zinc sulfide ore in a fluidised bed furnace type roasting unit was reported. The coils are prone to service degradation and subsequent failure due to the extreme operating conditions (920–960 °C). Severe corrosion attack and cracks were seen on the outer surface of the tube upon visual examination. The optical microscopy performed at the crack tip confirmed the deformation induced pearlitic banded structure. The corrosion products at the failure regions were rich in iron and zinc as revealed in the analysis by SEM with EDS. The galvanic corrosion between Fe and Zn is found to be the primary cause of the failure. It is hypothesized that the type of corrosion is possible with the zinc oxide acting as cathode with reference to the coil tube's outer surface. The selective corrosion resulted in the preferential corrosion attack and led to the premature failure of the tube.

1. Introduction

Zinc is found in the earth's crust primarily as zinc sulfide (ZnS). Zinc smelting is the process used to convert zinc concentrate into pure zinc. Roasting is a primary processing step in zinc smelting. Among the existing roasting processes, fluidized bed roasting is commonly used. It is the process of oxidizing the zinc sulfide concentrates at elevated temperatures. The feed material is zinc sulfide to the furnace [1]. Concentrate mixture is fed from the furnace side and air is blown from the bottom of the furnace through the wind box, which contains several nozzles for air entry with a defined flow rate. The blown air keeps the concentrate in fluidised condition. The reaction between ZnS and oxygen is an exothermic reaction and the temperature of the roasted ore reaches around 920–960 °C [2]. The roasting reaction is described as follows

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2 \quad \Delta H < 0$$

The heat generated from the exothermic reaction in the furnace is partially removed via the circulation of water through an assembly of tubes installed in the furnace. These tubes are typically called as cooling coils and are generally positioned in the upper and the lower half of the furnace. The material specification of the cooling coils is SA 510 Gr.A in the current investigation. In recent years, failure analysis of carbon steel was reported in many articles as localized corrosion in oil gas separator [3], ammonia evaporator wall thinning [4], high temperature sulfidation of carbon steel tubes [5], failure of super heater tubes [6] and

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http://dx.doi.org/10.1016/j.engfailanal.2017.01.004
1350-6307/

galvanic corrosion in boiler bank tubes [7]. However, failure investigation of fluidised bed cooling coils by localized corrosion is not reported.

In this article, failure of a cooling coil tube of a zinc roasting furnace is reported. The failure is systematically investigated with several characterization techniques on the failed surface of the tube [8]. The cause of the failure is found to be galvanic corrosion between zinc and iron. The observations, analysis and results are discussed in detail.

1.1. Description of cooling coils in zinc roaster

The furnace hearth area consists of 125 m^2 of circular bed. A total of eight similar sets of cooling coils with 50 m^2 heat transfer area each were aligned uniformly at upper and lower halves of the furnace. A failure in the cooling coil tube located in the upper half of the furnace was noticed. In the upper half region of the bed, the cooling coils' external surface is in physical contact with a fine bed of roasted zinc ore in fluidized condition at about 950 °C. The flow rate of air that is blown into the furnace is 62,000 Nm^3/h at a pressure of 250 mbar. The boiler water was circulated inside the cooling coils at 256 °C and 44 bar.

2. Experimental procedures

The chemical composition of the failed tube sample was analyzed using an optical emission spectrometer (OES) (Model: Spectrolab, Germany). Surface characteristics at the failure region of the tube were analyzed using stereo microscopy (Model: Leica, Switzerland). The microstructure of the sample was evaluated using optical microscopy (Model: Leica, DMLM Switzerland) after etching with 2% nital solution. Fractographic analysis was performed using scanning electron microscopy (SEM) (Model: JEOL JSM 739A) to ascertain the nature of failure. Energy dispersive spectroscopy analysis (EDS) was employed to determine the chemical nature of the surface deposits.

Fig. 1. (a) Failed cooling coil tubes in as received condition. (b) Close visual observation near the failure.