



Investigation on Heat Exchanger Pipe Failure

Papa Rao Mondli · D. Satish Kumar · Marutiram Kaza · Anil Bafna

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Abstract Convection heat exchangers are commonly used for heat transfer in high-temperature furnaces and processes. Pipes from U-bundles of a convection section of a MIDREX direct reduction ironmaking unit heater which carries reducing gas have been investigated for failure analysis. Repeated failures had occurred at a specific location. Samples of the failed pipe were subjected to microscopic and metallographic characterization. Inner diameter erosion and metal dust, carbides, oxides, and carbon were found at the failure location. Optical microscope revealed severe carburization on the inner surface that was in contact with heat exchanger gas. Coarse carbides at the grain boundaries accelerated the wear and corrosion by intergranular cracking. The reducing gas composition (with CO), dust composition (with carbides), and exposed temperatures (> 400 °C) confirmed that metal dusting is the cause of the failure. The high-temperature corrosion of steel is caused by hydrocarbon gases which form thermodynamically metastable carbides of the base metal. Such failures can be avoided by maintaining the pipe surface temperatures below 400 °C or using pipes manufactured from high-temperature-resistant steels.

Keywords Convection heat exchanger · Corrosion · Metal dusting

Background

JSW Steel has a 1.2 million ton per annum (Mtpa) direct reducing iron (DRI) plant based on the MIDREX process at its Vijayanagar, India works. It utilizes Corex gas to produce hot DRI for subsequent use in an electric arc furnace. Corex is a smelting reduction process which produces molten hot metal and generates high caloric export gas. In the DRI process, the Corex export gas and recirculated top gas from the MIDREX shaft furnace are mixed and compressed and subjected to a process to remove CO₂. The gas is then heated to the required process temperature in a convective heat exchanger. This heated gas is then used for the direct reduction of iron ore pellets in the MIDREX shaft furnace. The convective heat exchanger where the gas is heated is a cross-flow, unfinned tubular heat exchanger system where the reducing gas consisting primarily of CO and H₂ (54% CO, 30% H₂, 6% CO₂, 2% H₂O, and 1.5% CH₄) at 1.5 bar pressure is heated from 40 to 460 °C. The heat exchanger is a box-shaped chamber with a burner and combustion chamber at one side and an exhaust line on the other side. The heated air flows through four U-shaped tube bundles as shown in Fig. 1. The gas to these tube bundles is supplied by interconnected headers. Several grades of steel are used in different bundles based on its distance from the burner and combustion chamber and the exposed temperature. Puncturing and thinning of these heat exchanger tubes have been reported primarily in bundles 2 and 3. The failed steel tubes are of ASTM-A335-P11 grade having wt.% as 0.012% C, 0.45% Mn, 0.4% Si, 1.25% Cr, 0.5% Mo with the initial thickness of 4.4 mm. These pipes were designed for long life, and such premature failures are an unexpected phenomenon that has not been previously reported. Erosion problems on the outside of tubes resulting from impingement of wet, high-velocity gases such as

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Heat Exchanger Failure Investigation Report

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Heat Exchanger Failure Investigation Report:

Heat Exchanger Failure Austin Mwana, 2018-06-11 Academic Paper from the year 2018 in the subject Engineering Metal Engineering Metal Processing Metal Structure grade B Robert Gordon University Aberdeen course Oil and Gas Engineering language English abstract As a Corrosion Expert this report centred around the failure investigation of a shell and tube heat exchanger due to corrosion mechanisms The different types of corrosion its effect resulting to the failure and possible solutions and recommendations were submitted to the client for further action The report also sheds light on the alloys used for the design and better alternatives to be used to prevent future degradation of the shell and tube heat exchangers *Heat exchanger failure investigation report* Ataliba Miguel, 2014-03-10 Technical Report from the year 2013 in the subject Materials Science grade B Robert Gordon University Aberdeen course MSc Oil and Gas Engineering language English abstract A high pressure gas cooler located in an offshore platform have been operating for more than 10 years Throughout that period the gas cooler have been subjected to several tube failures the failures have caused gas leak from the tube side Several materials upgrades have been used to contain the tube failure The last choice was to use a more corrosion resistant material Hastelloy C22 Crevice corrosion has been reported as the primary failure mechanism The tube and tube plate joined surfaces have been exposed to high temperature which is relatively higher than the critical crevice temperature of Hastelloy C22 There was a poor heat transfer between the shell side fluid and tube side due to a small heat transfer area and low fluid velocity in the affected zone Stress corrosion and fatigue corrosion accounted for the secondary failure mechanism which ultimately caused a crack in the tubes Other possible reason identified to cause crevice corrosion was the mechanical rolling expansion technique Oftentimes it creates rear crevices on the tubes with enough geometry to develop crevice chemistry Mitigation methods such as hydraulic expansion technique heat treatment for residual stresses and baffle design enhancements have been proposed in this report Key words shell and tube heat exchanger failure Hastelloy C22 material tube failure localized corrosion crevice corrosion internal pitting corrosion **Interior, Environment, and Related Agencies Appropriations for 2018** United States. Congress. House. Committee on Appropriations. Subcommittee on Interior, Environment, and Related Agencies, 2017 *DP*, 1962 **Scientific and Technical Aerospace Reports**, 1995 *Energy Research Abstracts*, 1990 *Fossil Energy Update*, 1978 **Technical Reports Awareness Circular : TRAC.**, 1987 **Fretting Wear, Fretting Fatigue and Damping of Structures** Toshio Hattori, 2023-12-26 This book provides a comprehensive overview of the mechanical distinctions between fretting damage under axial or bending external forces and fretting damage under a torsional load It emphasizes the importance of studying practical accident cases to efficiently acquire technical skills The book is structured around the fundamental technologies of material science tribology and mechanics which are vital for understanding and addressing technical issues The author has incorporated all fretting countermeasure technologies which were previously often sensory and empirical in nature and repositioned them as

technologies grounded in fundamental principles The book proposes an economical approach to product operation that maintains reliability by integrating not only design technology but also maintenance practices It delves into specific materials such as titanium alloys and aluminum alloys which have seen increased use for weight reduction in industries like aerospace In this book Critical Distance Stress Theory that can easily derive the fatigue limit and fatigue life of the stress singular field at the contact edge was presented As a result the fretting fatigue strength and life can be predicted from the same FEM stress analysis as the normal stress concentration part And finally introducing a novel fretting mechanical model the book focuses on scenarios where pressure force N and repeated tangential force F are applied to two planar objects with the tangential force being transmitted solely through friction at the contact surface This model finds relevance in turbine blade connection structures among other applications The author references Asai's research example which encompasses fretting mechanical analysis fretting wear evaluation fatigue assessment and structural damping evaluation using this model

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