TCR Engineering Services

Failure Analysis and Investigation Services

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Failure Analysis and Investigation Services

TCR Engineering Services (TCR) and her associate company TCR Advanced Engineering have completed more than 300 failure investigation assignments, including 50 major projects on manufacturing or metallurgical failure analysis on ASME boiler and pressure vessels, Aircraft /Aerospace, Gas turbine engine components, Oil and gas transmission pipelines, Food processing equipments, Heat exchangers, Medical supplies, Automotive components, Refineries, Petrochemical plants, Offshore structures, Industrial machinery, Weldments and Ships.

TCR's failure analysis strength is in evaluating high temperature and high pressure failures. The Failure Analysis Team at TCR Engineering has experience in the materials, failure analysis, metallurgical, welding, quality assurance, and forensic engineering fields and is conducted by engineers holding advanced degrees in metallurgy, and mechanical, civil, chemical, and electrical engineering.

TCR Engineering works with clients to plan the failure analysis before conducting the investigation. A large amount of time and effort is spent carefully considering the background of failure and studying the general features before the actual investigation begins.

TCR uses a methodical approach to determine the mode and root cause of a failure. For experts of TCR, Failure analysis or problem solving is more than just brainstorming a solution to an identified problem. Successful analysis is achieved through a structured technique which uncovers the facts of the incident and adheres to a defined process for every step of the analysis process.

Failure Analysis Objectives

The first step in managing the actual failure analysis effort is to determine what you expect from the final outcome. During TCR's initial meeting with clients we develop a charter that clearly delineates the terminal objective of the analysis. This is further enhanced through the development of critical success factors that outlines whether or not the terminal objectives have been obtained.

At TCR Engineering, we adopt a disciplined vertical problem solving methodology used to determine levels of root causes of specific failure events. The following process is necessary to implement a successful failure analysis project.

Prioritize - Determine what is most important to work on.
Analyze - Analyze the failure event to determine root causes.
Recommend - Develop recommendations as solutions to the causes are discovered.

The TCR Engineering Approach

TCR Engineering Services failure analysis team is always headed by a senior metallurgical engineer who has the following characteristics:

- Ability to remain unbiased and reject conventional wisdom.
- Ability to facilitate a group of people toward a common objective.
- Trained in logic tree approaches to failure analysis.
- Affinity for listening and questioning for understanding.
- Patience and perseverance.

Procedure to conduct a Failure Analysis

Cause of failure is determined using state-of-the-art analytical and mechanical procedures and often includes simulated service testing. A combination of analysis and physical testing locates problems and provides recommendations for solutions.

In the course of the various steps listed below preliminary conclusions are often formulated. If the probable fundamental cause of the metallurgical failure becomes evident early on in the examination, the rest of the investigation focuses on confirming the probable cause and eliminating other possibilities. The metallurgical failure analyst compiles the results of preliminary conclusions carefully considering all aspects of the failure including visual examination of a fracture surface, the inspection of a single metallographic specimen, and the history of similar failures.

The complete evaluation sequence is summarized as under:

- Collection of background data and selection of samples
- Preliminary examination of the failed part
- Complete metallurgical analysis of failed material
- A through examination of the failed part including Macroscopic and Microscopic examination and analysis (electron microscopy, if needed)
- If necessary tests may also include Weld Examination, Case Depth, Decarburization Measurement, Coating/Plating Evaluation, Surface Evaluation and/or Grain Size Determination
- Chemical analysis (bulk, local, surface corrosion products, deposits or coating and microprobe analysis)
- Tests to simulate environmental and physical stress that may have played a role in the failure
- Analysis of fracture mechanics.
- Selection and testing of alternative products and/or procedures that will significantly improve performance
- On-site evaluation and consulting services and Formulation of conclusions and writing the report (Including recommendations)

The Failure Analysis Report

The failure analysis report represents the culmination of the analysis effort and the beginning of failure elimination. The goal of any failure analysis by TCR is targeted towards the elimination of identified causes.

The completed failure analysis report includes the following sections:

a) Description of the failed component
b) Service condition at the time of failure
c) Prior service history
d) Manufacturing and processing history of component
e) Mechanical and metallurgical study of failure
f) Metallurgical evaluation of quality
g) Event Summary of failure causing mechanism
h) Recommendations for prevention of similar failures

The final failure analysis report provides solutions with expected returns on investments but also identifies how the failure occurred in the first place. To accomplish this event summary, a description of the failure mechanism and list of recommendations are included in the report.

The event summary is nothing more than a brief description of how the failure was first noticed how long it has been going on and the method(s) used to isolate or mitigate the consequences of the failure. TCR will examine the Service condition at the time of failure and record the components Prior service history including Manufacturing and processing history of component.

The failure mechanism can be thought of as a summary of the root cause(s) that led to failure occurrence. TCR will chronologically characterize the things that must occur in order for the failure to manifest itself. The report will outline the Mechanical and metallurgical study of failure including the Metallurgical evaluation of quality.

The list of recommendations will explain what, when and who (if TCR consultants are on the project) is going to be responsible for implementation, and also include a recommendations for prevention of similar failures.

Full Service Material Testing Laboratory

The Failure analysis team is backed by our well-equipped material testing laboratory in Mumbai, India. Founded in 1973, TCR Engineering is India's foremost NABL and ISO 17025 accredited independent material testing laboratory.

The core services TCR provides include Mechanical Testing, Chemical Analysis, Positive Material identification (PMI), Non Destructive Testing, Metallography, Corrosion Testing, Failure Analysis, Raw Material Inspection, Metallurgical Product evaluation, Engineering Research and Consultancy.

TCR tests ferrous and non-ferrous metal, casting & forging, sheet metal, bar, pipe, stainless steel, nuts, bolts, engineering goods, non-metallic materials such as polymer, ceramic, glass, machined parts, and machine tool components as per international specifications or client-specified standards.

Engineers, Chemists, Metallurgists & Technicians, at TCR, have the qualifications, the education and the experience to meet rigorous standards in the testing field, whether serving the Private and Public Sector, Government or the Military.

Metallographic and Failure Analysis Facility

TCR has all tools required for conducting a modern failure analysis, such as:

- Metallurgical Optical Microscope with Image Analysis system LECO 500(USA) with 300X facility. For study fracture surface at low magnification and to decide areas to be studied at still higher magnification.
- Scanning electron microscope with EDAX. For study of high magnification fractography in critical situations. To study surface analysis of metal, corrosion product or localized areas.
- Stress Analyzer: To detect level of stresses in metal.
- Complete Mechanical and Chemical Testing Equipment at our laboratory.
- Dilatometer: To measure volume changes while heating and cooling.
- Equipments and accessories required for preparation of metallographic samples including Diamond saw cutter, Mounting press, Rough grinder, Belt polisher, Wheel or disc polisher, Electrolytic etcher polisher and a Microscope with attachments like micro-hardness testing.
- Micro Hardness Tester
- In-situ Metallography Kits

Failure Analysis Team

The Failure Analysis Team is jointly headed by Mr. Virendra Bafna (MD, TCR Engineering) and Mr. Paresh Haribhakti (MD, TCR Advanced Engineering).

Virendra Bafna, Founder and Managing Director at TCR, is a gold medalist from the University of Indore and has two masters degrees to his credit. He has done Master of Engineering from the University of Toronto, Canada and Master of Industrial Management from the Clarkson College of Technology, Potsdam, New York.

V.K. Bafna is a member of various professional organizations such as American Society for Testing and Materials (ASTM), Institute of Standard Engineers, ASM International, NACE, Non Destructive Testing Society of India, and Indian Institute of Metals. His vast expertise in the field of laboratory testing has brought numerous laurels to TCR notable amongst them is an award of appreciation from the Indian Space Research Organization (ISRO) for the company's contribution to the Project ASLV.

Paresh Haribhakti is a B.E. (Metallurgy) M.E. (Materials Technology) from M.S. University, Vadodara. Mr. Haribhakti has done basic research in study of hydrogen embrittlement of steels and stainless steels. Mr. Haribhakti previously worked as trouble shooting metallurgist for India's largest fertilizers and petrochemicals complex, GSFC Ltd., Vadodara for nearly 10 years.

His areas of interest are microstructure degradation of components exposed to high temperature and high pressure. He has working experience of more than 250 failure investigation cases of power plants, fertilizers, chemicals and petrochemicals industries. He has solved materials engineering problems and performed failure analysis on components from petrochemical plants, oil and gas transmission pipelines, offshore structures, ships, pharmaceutical plants, food processing equipment, gas turbine engine components, and weldments.

Mr. Haribhakti investigates the available physical evidence, and performs the necessary tests to develop the most probable accident scenario. He simplifies complex engineering theory into easy to understand and useable concepts.

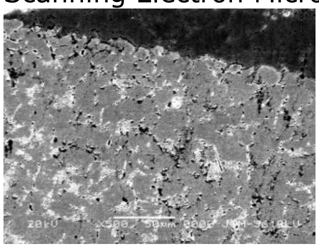
He uses simple analogies, every day examples, and laymen terms to explain data and findings so clients, corporate executives, government officials, or attorneys may easily understand engineering concepts.

Brief Failure Investigation and Analysis Case Study:

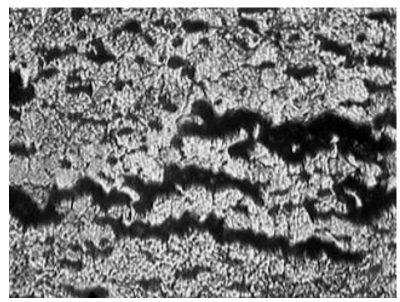
Primary Super Heater R-4 Zone Tube of a 140 Mw Boiler

The MOC of tube is TU 15 CD 205 .The service life of tube is 7 years before failure. The steam temperature & pressure of tube are and 450°C and 140 kg/cm^2 respectively. The tube has OD 63.5mm and ID 5.5mm. Tubes are located horizontally with flue gas passes vertically.

Scanning Electron Microscopy (SEM):



Upon SEM examination conducted by engineers at TCR, it revealed presence of inter-granular cracks and presence of numerous creep cavities at grain boundary. Presence of micro-cracks are observed more towards outer surface and near by crack region. Severity of cracks and cavity reduces when we move away from the main crack.

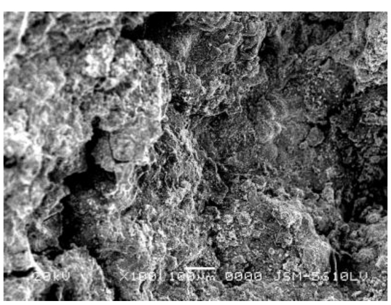


Microstructure Examination:
Crack displayed inter-granular nature of propagation with many small parallel cracks adjacent to main crack is observed. This maginification was done at the TCR Engineering laboratory using a Leco Image Analyser at 300X.

In present case the failure of tube seems to have occurred due to long term over- heating, above allowable design temperature, could be due to higher velocity of flue gas at this region or impingement of flue gases on tube surface facing flue gas or improper steam flow.

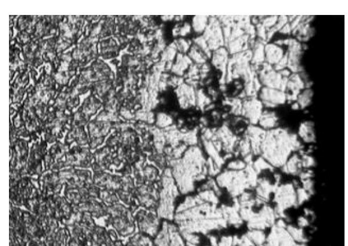
Radiant Coil of a Cracker Furnace H-130 Refinery

In a bottom fired furnace tube failure have experienced service of 14 months against the normal life of 6 to 7 yrs. MOC of tube is 25 Cr/35 Ni. The average tube metal temperature remains between 1000 to 1100 ºC temperatures. As per the manufacturer data, these tubes are designed for 1150ºC. The pressure inside the tube is 1 kg/cm^2 g.



Scanning Electron Microscopy (SEM):
SEM analysis conducted by failure investigation team from TCR Engineering revealed a progressive nature of fracture especially towards OD side.

However, majority evidences on fracture surface were masked under heavy scaling, which is generally expected under such service.

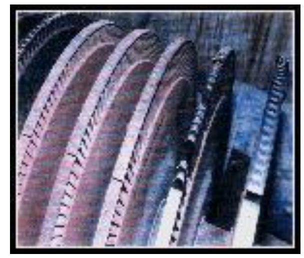


Microstructure Examination:
The crack is associated with carburizing more so at outer surface with decreasing the depth of carburizing towards ID. Another important evidence of crack originating from

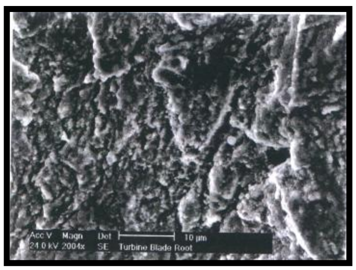
outer diameter and progressing towards ID. This maginification was done at the TCR Engineering laboratory using a Leco Image Analyser at 300X.

In present case the failure of tube has occurred due to localized overheating, which reduced ductility and failed under operational vibrations. TCR recommends looking in to the possibility of development of high temperature at the time of decoking operation.

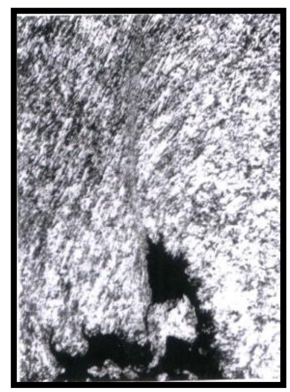
8th Stage Blade of a Steam Turbine



After 8-years of useful service life, a steam turbine was reported to have been working with abnormal vibrations. When turbine was opened five blades of 8th stage were found in broken condition from the root. Steam turbine operates with steam temperature of 770°F & working pressure at 568.3 Psi.



Scanning Electron Microscopy (SEM):
Fracture surface kept under SEM show multiple origins of the fracture and clearly shows progressive mode of failure. Fig. suggest rubbing of the metal surface where the failure had occurred.



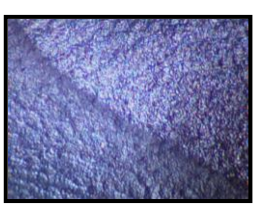
Microstructure Examination:
Microstructure on cross section of blade and showing the defect of deformation. At higher magnification crack shows branching nature progressing in the forwarded direction i.e. perpendicular to the central axis seems to have followed trans-granular path.

Failure of 8th stage blade has occurred due to corrosion fatigue, initiated at most stressed area. Only one blade was submitted for investigation. It is difficult to pin point which blade failed first.

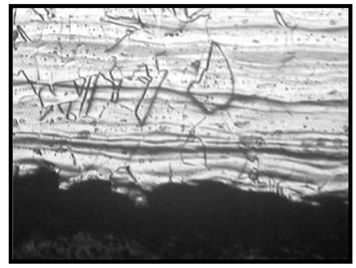
Sac Plant Piping Going to V-801

In a Sulphuric acid concentration plant, as a part of process, condensate is chilled in a heat exchanger. The line, which is connected from heat exchanger (E08-3) to vacuum pump, one elbow was reported to have leaked and needed replacement.

Severe corrosion was reported inside the replaced pipeline within 10 days of operation. The extent of corrosion was so severe that entire replaced pipeline reduced to paper thickness with punctures. The pipeline is operating with 1 to 2% H_2SO_4, 0.5% HNO_2 and 0.6 to 1.0 % HNO_3 at 10 to 20°C temperatures.



Low Magnification Examination:
Low magnification examination was done by the failure Analysis and Investigation team from TCR Engineering to find out the corrosion characteristics. Internal surface of pipe, weld and elbow showed severe corrosion on pipe. The close-up view of corroded surface inside the pipe show effect of general corrosion and flow pattern. Leakages observed in the form of openings between weld and pipe.



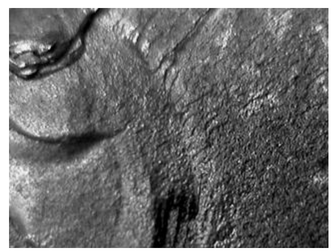
Microstructure Examination:
Uniform dissolution at ID is observed under microstructure examination at a magnification of 300x at the TCR Engineering laboratory in India.

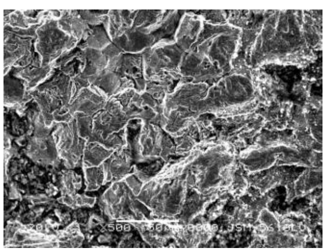
The fluctuation in Nitric acid concentration did not allow to stabilize passivity on newly fabricated pipeline resulted into severe corrosion.

Integral Pinion Shaft of a Cement Mill

Premature failure of integral pinion shaft was reported at a cement mill. The shaft failed after service life of approximately 15,000 hours (625 days) against intended design life of 30 years. The shaft is made from EN 10083-1 (1991) 30CrNiMo8 with through hardened and tempered to achieve 310-335 BHN. The shaft rotates at 133 to 134 RPM. The failure of the shaft noticed in form of cracks. Cracks were observed at 45° to the longitudinal axis of shaft.

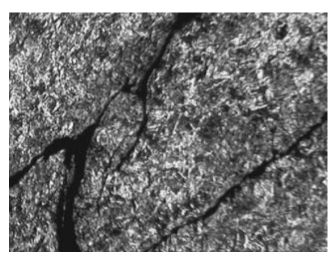
Low Magnification Examination:
Fracture surface at thread region shows relatively flat fracture whereas further fracture shows brittle nature with chevron marks. Fracture surface below thread region at keyway disclosed multiple ridges with relatively coarse fatigue striations.





Scanning Electron Microscopy (SEM):
SEM done by TCR Engineering revealed intergranular fracture with intergranular cracks. A fracture is brittle and shows inter-granular mode. Presence of fine cracks is observed.

Microstructure Examination:
Microstructure examinations at various section reveled that, general condition of shaft is in hardened and tempted condition. Further microstructure revealed presences of inter-granular cracks. The cracks are moving on prior austenitic grain boundaries and are observed filled with oxides. Presence of oxide inside the cracks is most important evidence in present case. This was done at a magnification of 560X at the TCR Engineering Services laboratory.



TCR Engineering Services concluded that the shaft failed due to pre-existed Heat treatment cracks under operational load.

Locations

We welcome service and technical inquiry, from simple questions to more involved interpretations of codes and specifications. We are located at:

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