

Fitness-For-Service (FFS)



Experts in NDT, In-situ Metallography, Fitness for Services and Failure Investigations, Mechanical Testings

Introduction

TCR Advanced Engineering Pvt. Ltd. has completed more than 1100 failure investigation, remaining life assessments and fitness-for-service cases which include projects on manufacturing or metallurgical failure analysis of ASME boiler and pressure vessels, Gas turbine engine components, Oil and gas transmission pipelines, Food processing equipment, Heat exchangers, Automotive components, Refineries, Petrochemical plants, Offshore structures, Industrial machinery and Shipping companies.

The petrochemical, oil and gas industry produces in the region of 1 billion barrels of petroleum per day. A failure would result in the shutdown of production affecting considerable loss. The failure analysis and the prevention thereof is an important technique in up-keeping oil and gas production. The FFS projects of in-service components is also of major concern to industries with respect to envisage impending degradation and get lead time for budgetary and other necessary planning for replacement. There are a number of extreme environments associated with the industry, which can lead to degradation of materials, categorically:

- Welding failures and issues related to weldability of components
- Localised corrosion
- Stress corrosion cracking
- Erosion corrosion.
- Microbial influenced corrosion
- Hydrogen induced cracking and life limiting damages
- High temperature degradation and creep life limitations
- Effect of sour service environment

TCR has the expertise and rich experience of remaining life assessment & FFS. Our team executes the job in consultation with the clients to plan the FFS tests. Great effort is made spending enough time before commencement of actual FFS activities to carefully understand the background of component and planning of required tests to quantify the present damage in co-ordination to theoretical correlation so as to later judge the remaining service life and fitness for service.

We have a methodical approach to determine the mode and FFS of Component. For experts of TCR, FFS 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.

Procedure for Fitness-For-Service (FFS)

Fitness for service assessment is performed to make sure that process plant equipment, such as pressure vessels, piping, and tanks, will operate safely and reliably for some designated period of time. Various international codes such as API 579 ASME FFS-1 provides a general procedure for assessing fitness for service. The assessment procedure evaluates the remaining strength of the equipment in its current condition, which may be degraded from its original conditions. Common degradation mechanisms include corrosion, localized corrosion, pitting and crevice corrosion, hydrogen attack, embrittlement, fatigue, high-temperature creep, and mechanical distortion. This

is a multi-disciplinary approach. The component of interest may contain flaws or other damage, or it may be subject to more severe operating conditions than the original design anticipated. The typical outcome of a fitness-for-service assessment is a “go/no-go” decision on continued operation.

TCR has substantial experience performing fitness-for-service assessment on a wide range of components. Our senior staff has been heavily involved to bridge the gap between standards and practical approach in guidelines with the API 579-1, ASME FFS-1 fitness-for-service standard, and serve on the committee that maintains this document.

The purpose of fitness-for-service is not to continue the component in its service beyond its serviceable life, but to ensure utilization of full potential concerning present damage assessment. The Fitness for service assessment is required either because the equipment has undergone some serious operational misshapen so as more severe conditions than the equipment was originally designed had crossed or flaws such as localized corrosion or cracks are observed or other design limiting factors.

Additionally, the fitness for service assessment of components can help setting up proper inspection schedules, modified maintenance procedures and more of online monitoring systems. The exercise in totality tends to assure safe and more economic operations of plant. The FFS procedures are complex needing the state-of-the-art analytical, metallurgical, mechanical tests and involve the multidisciplinary engineering analyses. A combination of physical testing and interpretation thereof, identifies a principally affecting damage mechanism under the prevailing operating conditions. The test results further can be implied for theoretical calculation of component's fitness for prescribed design specifications. Often, the irreversible damages to the equipment also call for alteration in original design and production specifications, for example lower rate of production or reduced stress condition, as per the feasibility of running the equipment.

All most all the materials exposed to high temperature are subjected to diffusion of lattice structure under stress. Despite having applied a constant stress, with lapse of time, the stress bearing capacity of the material reduces. This phenomenon is called creep damage and its severity is much dependent on carbide precipitation and its distribution in the alloy. The carbon steel grades are additionally susceptible to high temperature hydrogen attack (HTHA), wherein, the hydrogen diffuses in the material causing formation of methane gas by reacting with alloy carbides and forms cavities in the grain structure. Such damages often result in formation of micro cracks and threat a catastrophic failure without indicating a leak-before-break condition.

The following action plan is proposed for the FFS study of isomerization reactor.

- Collection of background data and history of failure.
- Conducting FFS assessment starts by following tests.
 - Visual examination
 - Dimension measurements.
 - WFMPI, DP or FDP of Weld Joints for surface flaws
 - Ultrasonic testing for Internal flaws.
 - Ultrasonic thickness measurement.

- In-situ metallography at critical locations.
- In-situ Hardness measurement
- If any defects are observed during the testing then they will be further characterised by Advanced NDT testing such as ToFD, FEA, Simulation, quantitative metallography of replicated microstructures, Scanning electron microscopy of Microstructure.
- Co-relation of investigative findings to published literatures along with brain-storming sessions with plant operational group for de-rating of design specifications, if necessary
- Certification for Fitness-for-service of equipment

The FFS deliverables

The FFS report represents the culmination of the analysis effort and the beginning of failure elimination. The FFS analysis report provides solutions with expected returns on investments and also provides information on various failure mechanisms highlighting probability on impending damages to the equipment. The completed report shall include the following sections:

- Description of the component, service history, manufacturing and processing conditions of component, problems faced and description of need for FFS study
- Theory on different damage mechanisms
- Detail reports for all tests proposed in Table 1 above.
- Event Summary of entire exercise
- Judgment on Fitness-For-Service of equipment up to Level-1 of FFS, and recommendations within 15 days of completion of work. However, preliminary report will be submitted within 2 days of completion of site work.

Material testing equipment available at TCR

TCR Advanced and its principal associated labs houses extensive range of material characterizing facilities to aid in characterising the materials properties. The testing facility of TCR is accredited by NABL as per international standard ISO/IEC-17025 : 2005.

Chemical analysis equipment

- Optical Emission Spectrometer
- Inductively coupled Plasma (ICP) & Atomic absorption Spectrometer.
- PMI (Portable XRF based spectrometer)
- Electronics Single Pan Balance (0.0001 gm Accuracy)
- Kjeldha's Apparatus for N₂ determination
- Full Fledged Lab Glassware for Chemical Analysis
- Strohlien's Apparatus for Detecting Carbon and Sulfur
- Electrolytic Apparatus with Platinum electrodes for Cu and Pb determination

Mechanical testing equipment

- Rockwell hardness tester –HRA, HRB, HRC & superficial hardness testing scales HR₁₅N, HR₃₀N, HR₄₅N, HR₁₅T, HR₃₀T, HR₄₅T
- Brinell Hardness tester -Load range 31.25, 62.5, 187.5, 500 & 3000 kgf
- Vickers Hardness tester Load range 5 - 120 kgf

- 40 T Computerized Universal testing machine with electronic Extensometer
- Vicker's Micro hardness tester Load range: 10- 1000 gms
- Charpy Impact testing machine.
- Jominy End Quench Test setup for hardenability measurement.
- Profile Projector
- Automatic programmable Heat treatment facility with chart recorder

Metallurgical testing equipment

- Scanning Electron Microscope With EDS analyser
- Inverted Metallurgical Microscopes with digital camera
- Low Magnification observation station with CCD attachment
- Metallurgical image processing workstation with Microstructure Characterizer(MiC) Software
- Stereo zoom microscope with standard accessories
- Portable Etching Cum Polishing machine model
- Metal Polishing with D. C. drive
- Portable Angle grinders & Polishing equipment's
- Low speed metallographic Cutting/ Sectioning machine
- Hot moulding machine
- Automatic Polishing Machine
- Heat treatment Furnace(up to 1100 C)

Corrosion testing equipment

- Potentiostat/ Galvenostat for Electrochemical Analysis and Corrosion studies.
- Salt Spray Test apparatus
- Complete set up and Erlen Meyer Apparatus for IGC tests as per ASTM A – 262
- Complete set up for conducting pitting and crevice corrosion testing
- Constant temperature bath range: 5- 80° C
- Constant Temperature bath Range : RT - 100° C

NDT testing equipment

- Acoustic Eye™, Dolphin G3 system
- Eddy current tester
- Internal Oxide thickness Gauge
- Ultrasonic Flaw Detector
- In-situ Metallography Kit
- Electro Magnetic Crack Detector (Yoke Type)
- Ultra Violet Black Light for WFMPI and FDP
- Dye Penetration Kit
- Ultrasonic Thickness Gauge
- High temperature probe.
- Coil type MPI Machine
- Portable Hardness tester Hardness tester UCI method with Diamond Inventor.
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Team members

Core team consisting of experts from various fields is formed as a first step of the investigation. The core team decides the approach to the investigation and decides the extent of testing required. The members of core team for failure investigations are. The members of core team of failure investigation are.

Shri Virendra Bafna, *Chairman*

Mr. V.K. Bafna is Chairman at TCR Advanced, He is also Founder and Managing Director of TCR Engineering Services, Mumbai, and a JV partner of TCR Kuwait, Saudi Arabia. A visionary with sound material sciences experience, strong business acumen and relentless sincerity, the TCR ADVANCED is maturing under his able guidance. With clear sense of purpose and urgency, Through hard work, dedication, integrity and love for his field, Mr. Bafna gained 35 years of practical experience in the areas of corrosion detection, chemical analysis, mechanical testing, failure analysis and materials characterization. He has introduced innovative methods for Corrosion Studies, Non Destructive Testing and is a pioneer in showcasing the advantages of XRF-based positive material identification to the industry.

Mr. Bafna, is a gold medallist 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, Institute of Standard Engineers, ASM International, NACE, Non Destructive Testing Society of India, and Indian Institute of Metals. He is an ex-committee member of ASM India chapter. Mr. Bafna's 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.

Mr. Paresh U. Haribhakti, *Managing Director*

Mr. Haribhakti is a B.E. (Metallurgy), M.E. (Materials Technology) From M.S. University, Baroda. He has done basic research in study of hydrogen embrittlement of steels and stainless steels. He has worked as trouble shooting metallurgist for India's largest fertilizers and petrochemicals complex, GSFC Ltd., Vadodara for nearly 10 years. His area of specialty is microstructure degradation of components exposed to high temperature and pressure. He has hands on experience of more than 500 failure investigation cases of Power Plants, Fertilizers, Chemicals and Petrochemicals Industries. He has provided services of failure investigation and In-situ metallography to major industries in the country and abroad.

Mr. Haribhakti had won first prize for metallography contest held at IISC-Bangalore - 1998 under NMD celebration by Indian Institute of Metals (IIM). There are several technical presentations and lectures delivered at National and International seminars to his credit. He is a member of different most of the professional bodies in the field of metallurgy.

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 weldment.

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.

Mr. Jaidev Patel, Chief Executive (Testing Division)

Mr. J. H. Patel is a B. E. (Metallurgy) from M.S. University Vadodara. He is having hands on experience in Industrial experience in the field of NDT for more than ten years. He is an ASNT Level –III P. T, U.T., M.P.T. and Eddy Current testing He was actively involved in developing Ultrasonic testing procedure for Railway tracks for Indian Railways as a consultant. He is in-charge of Testing Division of TCR Advanced Engineering Pvt. Ltd. for testing of Chemical, Physical and corrosion testing confirming to the National and International standards. He is also in charge of coordinating NDT site activities. His NDT expertise is also utilized in training and certifying NDT level II technicians. Under his able guidance more than 20 technicians have qualified for NDT Level II certification. He is actively involved executing NDT testing in life assessment and damage assessment jobs for TCR ADVANCED. His vast experience in NDT field and understanding of various national & international codes is useful in formulating test procedures for various testing activities.

Mr. Ketan Upadhyaya, General Manager – Reliability Engineering

Mr Ketan Upadhyaya is a B.E. (Metallurgy) from M.S. University of Vadodara and has experience of 22 years in the field of NDE, Acoustic emission techniques, Vibration measurement and signature analysis, Failure Investigations, Microstructure interpretation, Scanning electron microscopy and digital imaging system. He has worked as a metallurgist at India's largest fertilizers and petrochemicals complex, GSFC Ltd., His Job profile includes fabrication inspection, providing welding procedures for maintenance and relevant heat treatments, troubleshooting against organic and inorganic corrosion and microbial induced corrosion. He is a qualified analyst for Acoustic Emission testing (IISC Bangalore), Vibration Analyst VT-II (Entec IRD) and Ultrasonic Flaw Detection techniques. He is actively involved in Plant reliability Engineering and risk based inspection projects for different components such as heater piping, reactors and static equipment of petrochemical and refinery industries. He is well familiar with API/ASME/ASTM/JIS codes and ASM literature. His association with TCR Advanced Engineering strengthens the Remaining Life Assessment. FFS, Failure Investigations and Advanced Non Destructive Examination projects.

Dr. Rajendrakumar, Advisor

Dr. Rajendrakumar is a renowned metallurgist of our country. He is a doctorate from world famous University of Shefil, UK. Dr. Rajendrakumar was the Director of National Metallurgical Laboratory, Jamshedpur and a former Director of Regional Research Laboratory, Bhopal. Dr. Rajendrakumar

has more than 150 publications in national and international journals of repute. He has been a committee member of IBR for failure investigation. He has written three books on metallurgy.

Dr. P. B. Joshi, Advisor

Dr. P B Joshi is a professor in Department of Metallurgical and Materials Engineering, Faculty of Technology and Engineering, Maharaja Sayajirao University, Vadodara. He is a Ph. D. in Material Engineering. Dr Joshi is having more than 25 years of teaching experience in the field of metallurgy. He has more than 50 research publications in International journals & National journals, and authored a book titled "Materials for Electrical and Electronic Contacts".

Dr. K. Baba Pai, Advisor

Dr. Baba Pai is the Ex-Head of the department of Metallurgical & Materials Engineering Faculty of Technology & Engineering, M. S. University. He is Ph D from IIT Mumbai having more than 29 years of experience in Educational field. He began his career as lecturer in 1989 and became professor in the Metallurgical and Materials Engineering department since past 18 years. Under his able guidance more than 4 Students were awarded PhD. Presently three students are perusing PhD Under his guidance. He has more that 90 national and international publications in reputed journals. Dr. Pai is actively involved in providing Testing and industrial consultancy assignments for many industries of Gujarat. He is life member of many

Mr. Jagdish Baad, Consultant

Mr. Jagdish Baad is Bachelor of Technology in Metallurgical Engineering with First Class honors from IIT, Mumbai. He is having experience of 25 years in forge shop, steel, cast iron, S.G. Iron and Non-ferrous foundries. He has worked reached to Sr. Management position starting from the Engineer level. He has handled Turn key projects related to Foundry Mechanization, Quality Assurance and Product management of critical castings for turbine, material handling and wear resistance applications. Some of them are first of its kind. For last 12 years running an independent consultancy, related to TQM-Product Management of Castings & Forgings and metallurgical related turnkey projects. Well versed in kaizen, Edward Debono /Osborn techniques in creativity management. Energy audits related to metallurgical processes. He is Life member of various institutions such as Institute of Indian Foundrymen , Indian Institute of Metals ,Indian Society of Non-destructive Testing, Indian Institute of Welding Metallography Society of India, Alumni Association of IIT Mumbai.

Mr. Prakash Bhrambhatt, Consultant

Mr. Prakash Brahmbhatt is Ex – GM inspection dept of M/s IPCL Erstwhile RIL. His area of responsibilities during his association with RIL includes inspection & maintenance from health assessment & reliability/integrity angle for LDPE, PPCP, PBR-I, PBR-II, PP-IV, LAB, EG plants. Since last 32 years he is working in the field of fabrication, maintenance welding, inspection, testing, up

keeping, metallurgy/material science, corrosion, health assessment, reliability & integrity monitoring of piping & static equipment in the petrochemical process plants. Familiar with all different type API/ASME/ASTM/ASM etc. codes & standards in respect of inspection, NDT, welding & material of construction used in such plants in above areas/fields. He was appointed as an faculty on inspection & testing, metallurgy, welding in process plants in training centre of IPCL/RIL-VMD. He was also a competent person for pressure vessel testing for GFA compliance.

Legal

- The findings are based on data supplied by client.
- The suggestions / recommendations derived in the report would be recommending in nature without obligation to any legal and financial implication.
- The report of assessment shall not be re-produced except in full without the written approval of laboratory.