Issue 2

Jan 2011

SFA Newsletter

Happy New Year 2011!

About SFA

Objectives

Local centers

Welcome you all to join as members of SFA! Please see page 19 for membership form and contact email of secretary

message from our President

Dear readers, Happy New year 2011!

Warm greetings! I am delighted to find that the maiden newsletter was well received and, the patronage from many stalwarts is indeed a good sign. The feedback clearly vouches this fact. I appeal to readers to join the efforts of the executive members in achieving the steady progress of the society, as I recall the famous quote of Henry Ford:
Coming together is a beginning; keeping together is progress; working together is success.

K.Tamil Mani

Send us your feedback

Good luck to your pioneering efforts. You are the rising star on the materials horizon… and I wish you every success. *Dr P.Rama Rao*

It is excellent initiative. The contents are very impressive. Please put it on web sites with high connectivity like IIM, ASM, IGCAR, DMRL, NML etc.. Please consider my congratulations to you and the team. Dr.*Baldev Raj*, dir@igcar.gov.in

I must compliment you and your colleagues for bringing out this issue in such an exemplary manner. I am sure the members will certainly look forward to receiving future issues. It takes lot of efforts to sustain an activity of this nature and I certainly wish you all success in this endeavour- *Dr.RV Krishnan, formerly of NAL,* (rvkrishnan45@gmail.com)

Thank you very much Dr Jayakumar for the SFA Newsletter. I am still working on an article for the SFA. Shall get in touch with you soon. *Dr.V Ramachandran*, formerly of NAL, vramachandran71@yahoo.co.in

Contents, readability and quality of Newsletter are excellent. I would like to congratulate you and your team for planning and finally executing this work with precision. I will also try to include this information in BARC website. *Dr.K.Bhanumurthy, BARC, aditya@barc.gov.in*

This is a praise worthy action carried out by you. We shall be willing to help you out as and when required. M/s *Censico International, Agra*

Thanks for the newsletter and expecting more stuff in future- *Mr. M. Jayarama Bhat, Mangalore Refineries*

Newsletter is very good with lot of valuable information.. I appreciate your efforts in bringing out such a nice newsletter- *Mr.Jalaludeen, IGCAR ,jalal@igcar.gov.in*

Experts and experiences:

Dr P K De

Dr. K.E.Perumal

Dr.V.Kain

Sri S.Jalaludeen

Feedback restores the system to a known good state or improves further!

Feedback is the breakfast of the champions!!

From the Desk of Editors

. . . a failed structure provides a counter example to a hypothesis and shows us incontrovertibly what cannot be done, while a structure that stands without incident often conceals whatever lessons or caveats it might hold for the next generation of engineers.
Henri Petroski

To read more about him:
www.nytimes.com/2006/05/02/science/02prof.html

Happy New year 2011! You are browsing the columns of the second issue of the Newsletter of Society for Failure Analysis (SFA). The maiden issue received very good appreciation from many quarters. If you go through the feedback column, you may appreciate it. We took efforts to publish the newsletter in IIM web site and in this respect, we thank Prof. I Manna for his immediate cooperation to upload the newsletter on IIM web site:

http://www.iim-india.net/page.php?id=218

Like last time, we solicited articles from a few experts for the current issue. Considering the importance of environment for failures, a few articles by experts highlighting corrosion related failures are presented as you may browse the newsletter.

Whenever an engineering component is realised, a valuable process to perform on a whole product is endurance / failure testing. In mechanical terms, this is the operation of a product until it fails, often under stresses such as increasing vibration or environmental changes. This exposes many unanticipated weaknesses in a product. Therefore, we have added a unique article by seeking an article from a mechanical engineer who opined how a mechanical engineer should design and safeguard a component.

We thank all the authors for their contributions to the current issue. We take this opportunity to appeal to the Indian industry to use SFA as a forum to share their experiences on trouble shooting. Also, we seek their support to sustain the newsletter by contributing articles and case studies.

A great way to add content to this newsletter is to include a calendar of upcoming events. The details of important forthcoming international and national events are included; so also the books recently published on the subject.

As always, your news and comments, mailed to tjk@igcar.gov.in or param@igcar.gov.in are welcome. We wish you all free from failures and a joyful winter!

Kalpakkam (T.Jayakumar)
31-12-2011 (P .Parameswaran)
Editors

About the society

Aims and Objectives of Society for Failure Analysis

The aims and objectives of the Society shall be:

To serve as National Society to promote, encourage and develop the growth of "Art and Science of Failure Analysis" and to stimulate interest in compilation of a database, for effective identification of root causes of failures and their prevention thereof.

To serve as a common forum for individuals, institutions, organizations and Industries interested in the above.

To disseminate information concerning developments both in India and abroad in the related fields.

To organize lectures, discussions, conferences, seminars, colloquia, courses related to failure analysis and to provide a valuable feed back on failure analysis covering design, materials, maintenance and manufacturing deficiencies / limitations.

To train personnel in investigation on failures of engineering components and their mitigation.

To identify and recommend areas for research and development work in the Country relating to failure analysis.

To establish liaison with Government, individuals, institutions and commercial bodies on failure analysis, methodologies and to advise on request.

To cooperate with other professional bodies having similar objectives.

To affiliate itself to appropriate international organization(s), for the promotion of common objectives and to represent them in India.

To organize regional chapters in different parts of the country as and when the need arises.

To do all such other acts as the Society may think necessary, incidental or conducive to the attainment of the aims and objectives of the Society.

Know your local centers

2 day Workshop cum Seminar on

"Failure Analysis for Non-Metallurgists"

Society for Failure Analysis, Hyderabad Chapter conducted a workshop cum seminar on "Failure Analysis for Non-Metallurgists" during 8th & 9th October 2010 at Defence Metallurgical Research Laboratory, Hyderabad.

The seminar was inaugurated with lighting of the lamp, followed by welcome address by Dr G Malakondaiah, DS and Director, DMRL, Hyderabad: Presidential remarks by Dr K Tamilmani, DS and CE (A), CEMILAC, Bangalore & President SFA: Inaugural Lecture titled "Overview of Failure Analysis" by Chief Guest Dr A Venugopala Reddy, ARCI, Hyderabad; Vote of Thanks was proposed by Dr N Eswara Prasad, Sc 'G', RD (RCMA) & Co-Coordinator, Organizing Committee.

The Seminar was attended by 80 participants from DRDO Labs, BHEL, MIDHANI, BDL, ECIL, HAL and around 40 students of various disciplines from different Engineering Colleges. The seminar material was distributed to all the participants.

Various topics related to failure analysis like Methodology for failure analysis, Role of mechanical properties and fractography in failure analysis, Non-Destructive Evaluation and Quality Assurance in Failure analysis were covered during the seminar. The effects of fatigue damage and creep damage on failure analysis were also dealt with. A few case studies and experiences of failure analysts were also discussed.

In addition, live experience with failed components and different equipments and methods used for carrying out failure analysis were also demonstrated as a part of the Workshop. The Valedictory function was chaired by Dr P Venugopalan, DS and Director, DRDL and distributed certificates to all the participants.

We encourage you to join the society, Kindly fill up the application form (enclosed at the end of the newsletter-p21) and contact secretary: pjayapal59@yahoo.co.in ;

An expert is a man who has made all the mistakes, which can be made in a very narrow field- *Niels Bohr*

Failure Analysis, Plant Dynamics & Inspection Strategy

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Preamble

Failure analysis or the analysis of failure is extremely important exercise for all sorts of enterprises starting from medical, financial, family, academic, weather prediction, electronic systems, surface & ocean going transportation, aviation, chemical, petrochemical, thermal, nuclear power plants to name a few. The word 'failure' implies negative indications and now many other terminologies have been coined such as 'root cause analysis (RCA)', system reliability analysis, etc. Presently, in the era of computational simulation age, the often said proverb 'failure is the pillar of successes' is not appreciated, as everybody expects system should perform satisfactorily at the first time itself. As I understand, the SFA is more focused towards materials or the performances of plant components; the remaining part would be devoted on corrosion management, failure of industrial plant equipment and its analysis.

ASM Metals Handbook on 'Failure Analysis and Prevention' deals extensively on analysis of failures in various industrial sectors and also provides effective measures for failure prevention by improving product performance and reliability. In addition, there are a number of similar publications on failure analysis on industry / sector wise as well as mechanism based etc. Systematic studies on the reasons for unsatisfactory performance of any type equipment, facility / system etc. are of immense importance but in industrial scenario it is yet to occupy ***centre stage*** position like other engineering disciplines. There are various reasons for the same: presently failure analysis activities are mostly a 'fire fighting' type exercise and whenever it occurs, detailed failure analysis studies either in-house or by an external institute / lab is taken up. But most often, once the report is submitted, some short & long term measures are proposed, some of them may be even impractical. When such failures reoccurred, then only it may receive great attention. The main

- Failure analysis is considered post mortem type endeavors.
- FA report hardly receives deserving importance
- The main reason could be that Failure Analysis is not a continued process in the overall plant activities

reason could be that Failure Analysis or RCA is not a continued process in the overall plant activities. Also a few instances may receive proper feedback to designers of new plants or during plant expansion program. It is the general experience of the failure analysts that the FA report that is prepared with so much devotion and attention, but hardly it receive deserving importance. Plant dynamics are different—mostly focused on production, safety, return of investments, environmental, etc.

In view of this, failure analyses or RCA reports should be considered as "continued" processes in the overall plant activities, more focused, positive looking, budgeted and not a fire fighting type. After decades of research experience in high technology area, when one may steps in to the corporate world, it is realized something should be done to ensure FA remains at the centre stage along with the high profile plant managers / MBAs.

Process Managers / engineers desire record-breaking output under the existing process conditions. They hardly appreciate the failure analysis report, however appropriate it may be---what is desired is that no component should fail at all, by taking appropriate preventive measures. Failure analysis is considered post mortem type endeavor and is not very much appreciated in the overall plant activities. After considerable thought, risk-based inspection (RBI) strategy was introduced without much fun fare & of course, without any additional fund allocations. The outcome was great after one annual plant shutdown--plant performed continuously for record duration without failure of static components and consequently, the production increased to phenomenal height and plant management thanked almighty for such encouraging results. However, on detailed iteration, the importance of RBI program was realized. Thus, it is felt, if material scientists desire to remain on the centre stage of the plant; it is the RBI program that should be pursued. RBI procedure as per American Petroleum Institute (API) Recommended Practice (RP) 580 may be considered as an offshoot or complimentary to failure analysis & RCA. API RP 580 has been introduced in 2002 and some salient features of RBI program are highlighted in the next section

Risk -based Inspection --API RP 580

This standard provides general guidelines for formulating a long term risk-based inspection program for fixed equipment and piping to hydrocarbon and chemical process industries. Inspection methodologies, their frequencies, particular location to be inspected are all programmed on the basis of ***degradation mechanisms*** of the materials of construction of the particular equipment-fluid-operating parameters' combination. It is felt strongly that this RBI RP 580 has been generated from the feedback of failure analyses data. Over a century, vast knowledge / data have been gathered regarding the likely mode of failures of a host of industrial materials, when exposed to a particular environment under different thermo mechanical conditions. RBI could be considered as part of recognized and budgeted plant maintenance program and fits very well with any plant dynamics. Thus, all failure analyses results & other materials related data are brought into centre stage involving plant safety, health, and environment (SHE) through RBI program. It may be mentioned that RBI program has become very effective and popular in plants wherever it has been adapted and as of now this is very good avenue for materials and inspection experts to contribute directly.

In process plants, inspection plans are made to detect and evaluate deterioration in materials due to exposure to aggressive operating conditions. Briefly, type and effectiveness of inspection program varies widely; reactive programs covering known areas of concern; proactive programs covering a variety of equipment. One extreme would be the 'don't fix it unless it is broken" approach. The other extreme would be complete inspection of all equipment on frequent basis. In this contest, RBI represents the next generation of inspection approaches, which focuses attention specifically on the equipment and associated deterioration mechanisms representing the most risk to the facility. Further, in focusing on risks and their mitigation, RBI provides a better linkage between mechanisms that lead to failure and the inspection methodologies that will effectively reduce the probable risks.

RBI assessments are of three types: (1) qualitative, (2) quantitative and (3) semi – quantitative. In all these methods, type of data inputs differs and so as the risk probability values. In qualitative approaches, probability and consequence of failures are assessed from plant data inputs that are of descriptive type based on engineering judgment and experience. Obviously, the overall output vis-à-vis accuracy of results from qualitative analysis is dependent on the background and expertise of the analysts. Qualitative approaches are easily implemented and are most cost effective; however, they are mostly dependent on involvement of the metallurgical-corrosion-inspection experts. Here knowledge and expertise of failure analysts is most valuable besides co-operation of plant personnel at all levels. Feedback on plant performance, history, failures and their analyses are used effectively in assessing RBI and the associated improvement in plant availability, production etc. The plant management realized the importance and usefulness of failure analysis or the RCA studies. In this program, the extent of degradation of critical components is evaluated at certain interval. Based on the assessment, suitable measures are planned in advance to be executed during the forthcoming planned turn around. This action prevents failures and also arrests further deterioration of the components, if any. For example, some shallow cracks were detected on ID surfaces of pressure vessel- the moment they were detected, cracks are ground off with large radii of curvature---preventing further crack growth and increased component life for safe operation.

Quantitative RBI approaches are computer software driven that integrate all relevant information regarding system design, operational details, plant history, component reliability, plant personnel capability, accidents and potential environmental and health effects. This totally digital type approach assigns qualifying numbers to different events. This approach requires software experts in addition to engineering-materials facilitators / experts. Besides, all data right from facility design, materials description, details of component fabrication, pre-service inspection, and its acceptance standard, field engineering, installation details, plant operating history both normal and abnormal conditions, over production, component failures etc. Experiences reveal that correct data inputs require a lot of efforts of the plant operators and the return of investment is achieved after a long periods (~ 3 years or more). Most plant management expects quick results, and hence sometimes the program is discontinued within a short time.

Semi-quantitative RBI approach is intermediate between the two and it is designed to receive benefits of the previous two approaches i.e., speed of the qualitative and rigor of the quantitative. This approach prevents unscheduled component failures as the weak components are identified by proper inspection strategy and removed / repaired during the planned turn around of the facility. Again, the knowledge of materials experts is very much sought after for detailed component health assessment on a continuous basis. The role of materials experts becomes very important and thus RBI and failure analysis are complimentary to each other. Society of Failure Analysis (SFA) would serve very useful to industries if it takes up such issues, train young professionals and provide service to industries. As of now, in our country no awareness is available to take up such activities on a commercial scale. Some groups with foreign collaboration are available but not economical.

xxxxxxxxx

Reducing Corrosion Losses and Increasing Reliability through Failure Analysis: Principles & a Case Study

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Failures are common!!! Are they?

As per a newspaper report appeared several years back, a former Director General of International Atomic Energy Agency has requested the public at large to "take in their stride the possibility of nuclear accidents just as they accept other industrial accidents". He said

"We accept the fact that a tanker may sink, that methane gas in some coal mines my catch fire or explode and an aircraft may crash".

This statement is typical of the **common public opinion** that equipment failures in industry are natural phenomena and that they are normally accepted as part of the industrial activity. There are very few who realize the **great economic loss** incurred through such failures and that these failures can be prevented from repetition through careful analysis and documentation of such failures and implementation of the recommendations coming out of the failure analysis studies.

Among the various causes of failures of equipments, such as material defects, improper design, mechanical overloading and the environmental influence such as corrosion, the latter accounts for as high as 55% of the failures, particularly in chemical process industries. Several years back, a petrochemical plant, producing caprolactum, was completely wiped out overnight by a fire originating from a cracked pipe. The cause of the pipe cracking was a phenomenon called ***liquid metal embrittlement,*** a form of corrosion. An aircraft accident in mid air was attributed to "the failure of standby hydraulic system due to a ***corroded fuse"***.

All such incidents go to illustrate

the extent of losses corrosion can result in. It is unfortunate that insurance companies do not consider corrosion as a claimable loss as they treat the other forms of losses like fire, earthquake, flood, theft etc. This is essentially because corrosion, over the ages, is being considered a phenomenon which takes place gradually over a period of long time. The forms of localized corrosion which usually show up suddenly are not being accepted as "accidents", which truly they are.

The common practice, whenever failure occurs, is to replace the failed component as early as possible and to restart the operation. Though this trend is understandable, the possibility of such failures occurring again is overlooked. Consider the following extract from another news paper report:

"The power producing chain of equipments was shutdown for a short period to plug a leak in a heat exchanger. We could not complete all the related operations since there was pressure to recommission the system facing a serious energy crisis and we rushed up the job. Now a leak has developed again forcing a long shutdown of about three weeks.

As a result of this unexpected long shutdown, many daily workers both in the plant and down stream plants depending upon this power have been rendered jobless. The state's power supply has fallen by several million units per day"

This report forces us to realize the following:

- Grave consequences are usually overlooked
- A leak has been plugged, apparently without analyzing the cause of the leak, that is, without carrying out a regular failure analysis study, the utmost necessity and the importance of which has not been felt.

Several such incidents occur frequently in chemical, power, transportation and other industries. Some of them are reported, most of them are not. In the process, the affected component is consigned to the scrap yard thereby destroying evidence of scientific and technological importance.

Why is there such a reluctance to carry out failure analysis?

The classic reply is "there is pressure to recommission". Here one may aptly quote Siebert from his article entitled "Classic Blunders in Corrosion Protection":

"Too many times we allow the time pressures of the job to control our decisions –which just isn't too smart"

If the full time operating staff are not to be burdened with the task of carrying out "time-consuming?" job of failure analysis study, an outside agency should be detailed to carry out the necessary failure analysis. Careful documentation of such failures, reporting them accurately, impartially and effectively followed by the analysis of the root causes would, not only prevent such failures in the future, but also increase the plant efficiency. A study in a power plant has shown dramatic improvement in plant from a low value of 60% to a value as high as 70% over a period of 16 years, mainly attributable to vigorous incident reporting program followed by detailed analysis.

In short, "reliability" of equipments is achieved through detailed "failure analysis".

Case Study

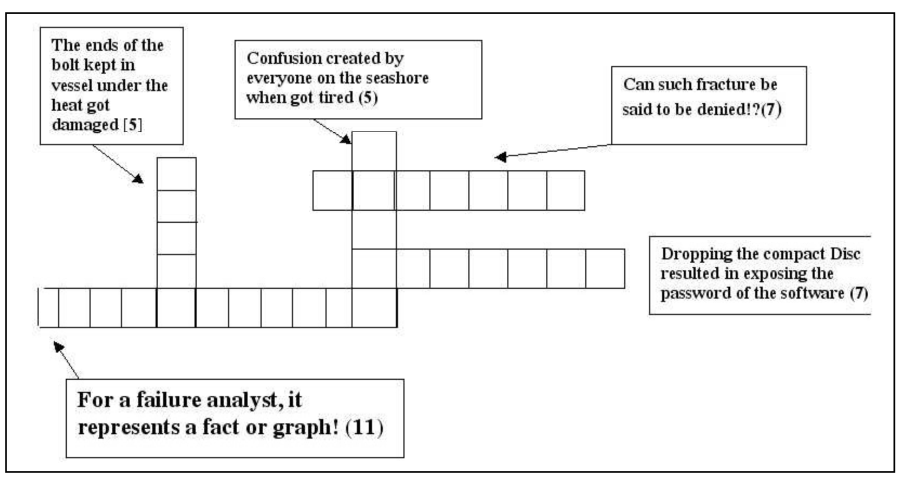
A medium size petrochemical plant producing a toxic organic chemical has been facing a series of corrosion problems in their process equipments and utilities. Each time a problem occurs, the practice was to rectify/replace the component and restart the plant. The particular problem shows up again. Only after the plant down time loss figures showed an alarmingly high value, the management took notice of the situation and ordered a detailed **downtime analysis** accompanied by a detailed technical **failure analysis** of each and every problem.

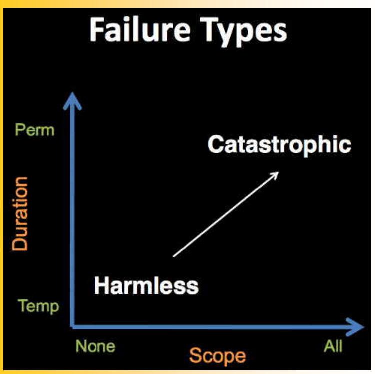
Every time the plant has to be shutdown and restarted due to some unusual corrosion problem. a document was prepared showing the stopping time, restarting time, period of downtime, the cause of the downtime and the action taken for rectifying each incident. The first year of such a program showed an accumulated production loss of 465 hours (20 days) attributable to the unusual corrosion problems alone. This is in addition to the planned shutdown, like regular maintenance, boiler check up and other cleaning shutdown periods. This period of 20 days is equivalent to an extra annual production loss of about 8.00%, which is substantially high for plant of any size.

The number of unusual corrosion problems occurred in the first year of such a study was 17 in process equipments, 4 in the cooling water circuit, 3 in the boiler/steam circuits and 2 in structures.

The management has started a program of Failure Analysis of every such unusual corrosion incident to be carried out by an independent outside agency and immediate implementation of the recommended measures by the plant personnel. Such a program is giving them rich dividends presently.

Crossword on failure analysis: Answers in last page





Single and dual phase flow accelerated corrosion in Indian nuclear power plants

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Materials Science Division, Bhabha Atomic Research Centre, Mumbai
* Nuclear Power Corporation of India Ltd., Mumbai

Flow accelerated corrosion (FAC) causes wall thinning of carbon steel components exposed to flowing deoxygenated water (single phase (SP)) or wet steam (dual phase (DP)). Final failure is ductile when the wall thickness is reduced to an extent that it cannot withstand the operating pressure. FAC has affected a large number of piping and equipments in all types of fossil, industrial steam, and nuclear power plants. FAC has affected a large number of carbon steel pipelines in the secondary circuit and has also affected the feeder pipelines in the primary circuit of nuclear reactors. The water/water-steam mixture in the secondary circuit leads to formation of a protective magnetite film on the internal surfaces of the carbon steel components. FAC is a process by which this normally protective oxide layer dissolves into the flowing stream by an electrochemical mechanism and the oxide layer becomes thinner and less protective. This is a corrosion process the rate of which is enhanced by (electro) chemical dissolution and mass transfer and is not a dominant mechanical degradation process. FAC does not occur in lines transporting dry steam. FAC is thus, an extension of the generalized carbon steel corrosion process in stagnant water. The following cases illustrate the occurrence of single and dual Flow phase FAC in carbon steel components and the distinct signature patterns that form on the surfaces.

Single phase FAC

Thinning of carbon steel components due to dissolution of protective oxide film and the base metal in the process water is termed as single phase FAC. The SP FAC rate depends on the hydrodynamic variables, metallurgical variables, and the environmental parameters. The micro pits formed by the initial selective attack of the carbon steel microstructure grow until they touch each other thus giving a rough appearance to the surface. The corroded surface on the inside surface of pipelines are characterized by overlapping "horse shoe pits" or "scallops" that give an orange peel appearance. These heavily corroded scallop surfaces (either oxides or the base metal) may dislodge and flow out with the high velocity process fluid, thus adding to the already high metal loss (dissolution) rate. The typical appearance of the surface affected by SP FAC is shown in figure 1 from a failure in 10% feed water line (secondary circuit) in Kakrapar Atomic Power Station unit-2. This failure had occurred downstream of a flow measurement device (orifice) due to high flow rates and turbulence generated for the flow. The size of the scallops is finer near the failed regions indicating higher thickness loss due to a greater extent of SP FAC as shown in figure 1. The XRD analysis confirms the presence of a thin layer of magnetite from the regions adjacent to the failed surface where thinning due to FAC was maximum (figure 2). The thickness mapping results also indicated that thinning had occurred over long distance from the location of failure as shown in figure 3. If the internal surface is not affected by FAC then the magnetite layer remains intact and the signature surface patterns are not formed as shown in figure 4 for a 150 NB 40 schedule elbow from Madras Atomic Power Station #1.

Dual phase FAC

The oxide dissolution mechanism is similar to single phase FAC but this kind of degradation occurs in pipes carrying wet steam. The FAC rate varies with the quality of steam that is the amount of moisture in steam. Surfaces exposed to this kind of dual phase attack have a "tiger striping" appearance. Figure 5 shows the surface features formed in a failed high pressure turbine exhaust pipe from the secondary system of a nuclear power plant. Formation of 'tiger striping is evident on the surface affected by DP FAC more clearly at a higher magnification.

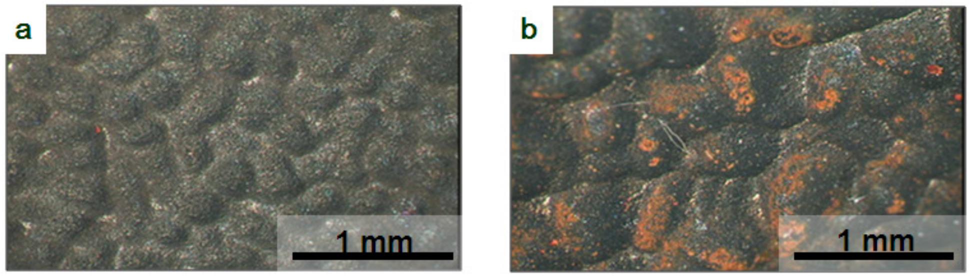


Figure 1. Scallop formation due to SP FAC, a) fine scallops near failed region, b) coarser scallops away from the failed region.

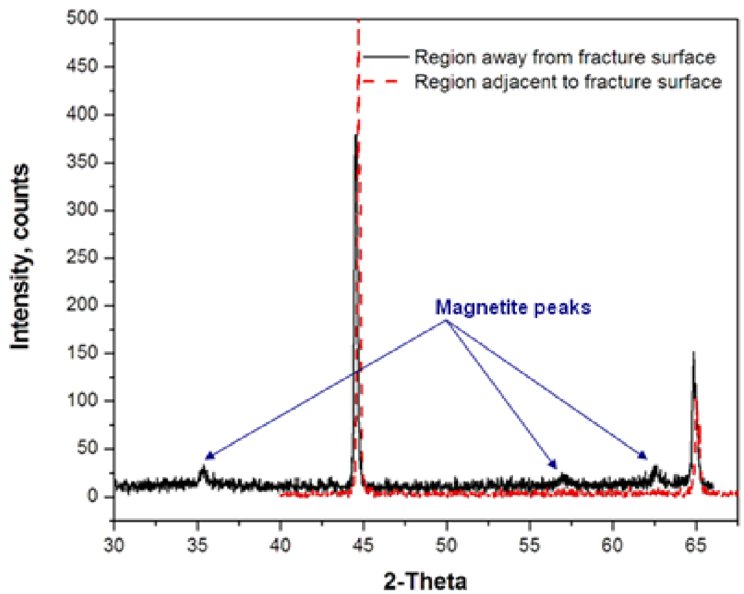


Figure 2. XRD pattern from two different regions indicating presence of a thin layer of magnetite from FAC affected regions.

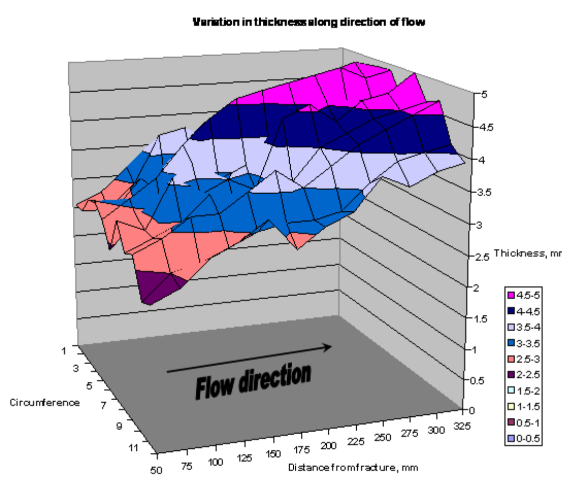


Figure 3. Variation in thickness in the direction of flow indicating thinning over long distances away from the failed region in a pipeline.

Mitigation of FAC

The operating conditions (temperature, pH, deaeration) prevailing in the secondary systems of the nuclear power plants and the piping material (SA 106 grade B) which limits alloying elements like chromium and copper to a maximum of 0.4 wt.%, favour FAC. Thus, thickness mapping of the pipeline and elbows (using ultrasonic inspection) are carried out periodically to measure the rate of thinning due to FAC. Care is taken to do the ultrasonic thickness measurements at the same location during every shut down period and the components are replaced when the thickness reduces below the critical limit. The existing grades of the piping material should be replaced with materials more resistant to FAC, containing higher quantities of chromium and molybdenum like SA 335 grade P11 or P22. A minimum in the FAC rates is observed in the pH of around 9.5. Better water chemistry control, especially pH, can reduce the FAC rates to a large extent. Dissolved oxygen (DO) in the range of 5-10 ppb reduces FAC rates drastically. Hence, stringent control of DO within this range will mitigate FAC to a large extent. However, adequate care should be taken to ensure that introduction of DO does not affect the healthiness of other alloys especially the copper based alloys or the steam generator tubing (alloy 800). Flow velocities may increase by 3-4 times at localised turbulent regions, enhancing the FAC rates even though the bulk fluid flow velocity may be low. Hence, prudent design improvements are also being implemented so as to minimise localised flow turbulence to minimise FAC.

We seek articles on the following topics from readers for future issues of SFA newsletter:
1) Reliability and failure analysis
2) Statistics in predicting failures
3) Failures in powder metallurgical components
4) Failures in chemical and petrochemical industries

- Editors

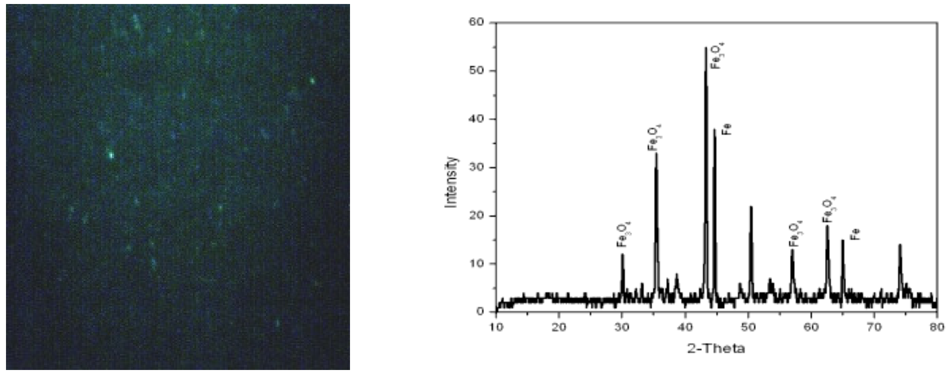


Figure 4. Surface not affected by FAC covered with magnetite layer and confirmed by XRD.

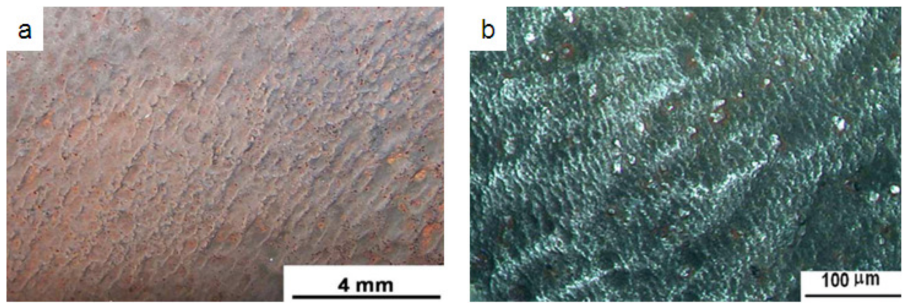
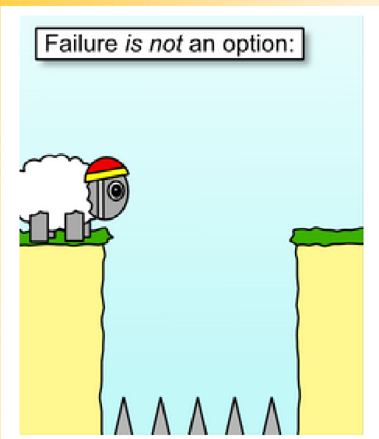
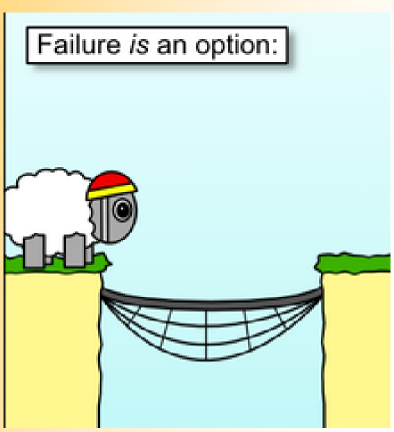


Figure 5. Component affected by DP FAC, a) at lower magnification, b) 'tiger striping' pattern seen at higher magnification of the region shown in (a).

References:

1. Atul Bhandakkar, "Flow Accelerated Corrosion and Control Strategies in the Secondary Circuit Pipelines in Indian Nuclear Power Plants", *Journal of Nuclear Materials*, Volume 383, Issues 1-2, 15 December 2008, pp 86-91 (2008).
2. Vivekanand Kain, S. Roychowdhury, P. Ahmedabadi and D. K. Barua, "Flow accelerated corrosion: experience from examination of components from Indian nuclear power plants", Proceedings of the international conference on Flow Accelerated Corrosion (FAC 2010) held at Lyon, May 4-7, 2010.





FAILURE ANALYSIS THROUGH STRUCTURAL ANALYSIS FOR REACTOR COMPONENTS

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Introduction

Failure analysis of metallic surface of any failed component provides a clue for the cause of failure like fatigue, creep, ductility exhaustion etc. Though the stress analysis has been done prior to its operation, failure occurs unexpectedly. This is because some of the parameters like temperature, pressure, static loading etc. might have crossed their normal operating limits due to various reasons including operation abnormalities and human errors. Also there may be design fault, which might have been overlooked at the design stage.

Thermowell failure in MONJU

There was failure of a thermowell in MONJU fast reactor in Japan [1]. The thermowell was having a sharp change in diameter, which causes stress concentration leading to failure. After identifying the cause of failure, the sharp change in diameter is modified with smooth change (Fig.1) [1]. Then the stress analysis of this modified thermowell predicted that there will be no more failure under the flow-induced vibration.

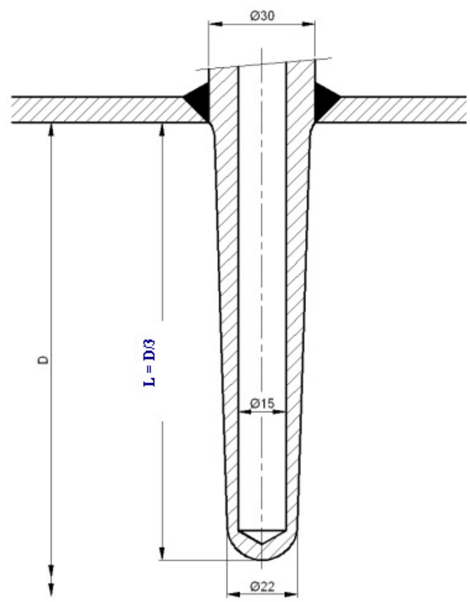

Fig. 1 Schematic diagram of Thermowell (D-pipe diameter)

The weir instability of thermal baffle

The weir instability of thermal baffle in superphenix fast reactor has caused its large vibration amplitude during the commissioning of the reactor [2]. This is because of unexpected instability of the weir baffle due to weir flow of sodium. There were coupled sloshing phenomenon and uncoupled single mode instabilities. These phenomena have been identified only through experimental scaled down models. Then the theoretical instability charts have been obtained through structural analysis with safe and unsafe regions of operations. This chart helped to modify the flow rate and fall height so that the operation is brought to safe zone.

Vibration of Sub-assembly

There was unexpected vibration of fuel subassembly in DHRUVA reactor at BARC, Mumbai [3]. This is because of resonance of Sub-assembly. This was solved by changing the natural frequency away from that of external excitation through careful stress analysis and design changes by providing a few slots on the foot of the subassembly [3].

Conclusion

Here are a few incidences briefed above where structural analysis helped to solve unexpected failure scenario and bring to the normal operation. There are many more such incidences where the structural analysis worked as failure analysis to suggest the proper modification to solve the problems.

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Society for Failure Analysis

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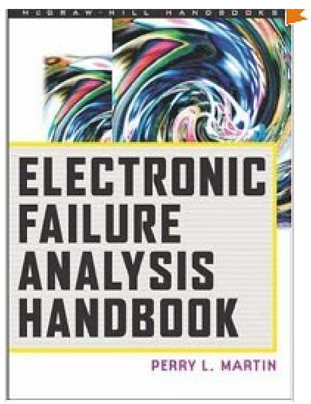
Events in the pipeline

- Pump Maintenance and Failure Analysis, Feb 24- 26, 2011;Charisma Careers Private Ltd., Vadodara 390020, I+91 265 6616173
- Metallography for Failure Analysis - January 10-14, 2011, ASM, USA

The man of learning lives even after his death

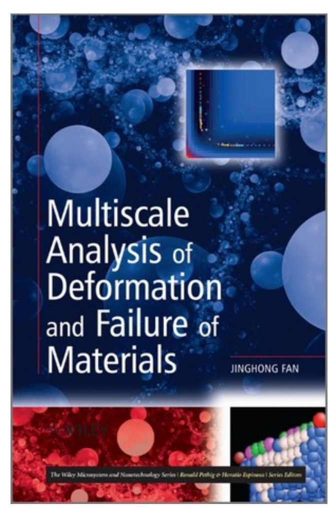
Yes, I admit it, I'm proud to say; "I work with failures!" Throughout the school years, Scientists and Engineers are taught how and why things work. It is rare to ever get more than a short anecdote about the failures, yet this is where the real learning, and the growth, occurs. People learn by making mistakes and taking corrective actions so that the same mistakes will not be made again- *Perry L Martin*

Books



Electronic Failure Analysis Handbook : Techniques and Applications for Electronic and Electrical Packages, Components, and Assemblies - Perry L. Martin -. Manufacturing processes can mature in a similar manner. The semiconductor/microelectronics industry embraced this philosophy and incorporated microelectronic failure analysis into the corporate culture. The result was miraculous increases in product reliability. The achievements of the microelectronics industry were admired by other electronics-related companies and, to some extent, duplicated. Electronic failure analysis is now common across a broad range of companies and electronics technologies yet it is difficult to find any documentation of these efforts. The Electronic Failure Analysis Handbook is an attempt to address this deficiency. The Handbook is presented in three parts: Part One is the shortest and deals with the uses of electronic failure analysis (EFA). Background on system and component reliability is presented, as well as an entire chapter on the use of EFA in product liability. Part Two deals with the techniques involved in performing EFA. Techniques include: electrical characterization, x-ray, IR-thermography, acoustic micro-imaging, photography, metallography, etc

Multiscale Analysis of Deformation and Failure of Materials systematically describes the background, principles, and methods within the exciting new field of multiscale analysis. It provides a digestible introduction to the complexities of the interdisciplinary field of multiscale modeling of deformation and failure analysis of materials, respecting the reader's need to critically think and absorb both information and perspective. This type of multiscale analysis has a broad scope of applications, encompassing different disciplines and practices and is an essential extension of mesomechanics.



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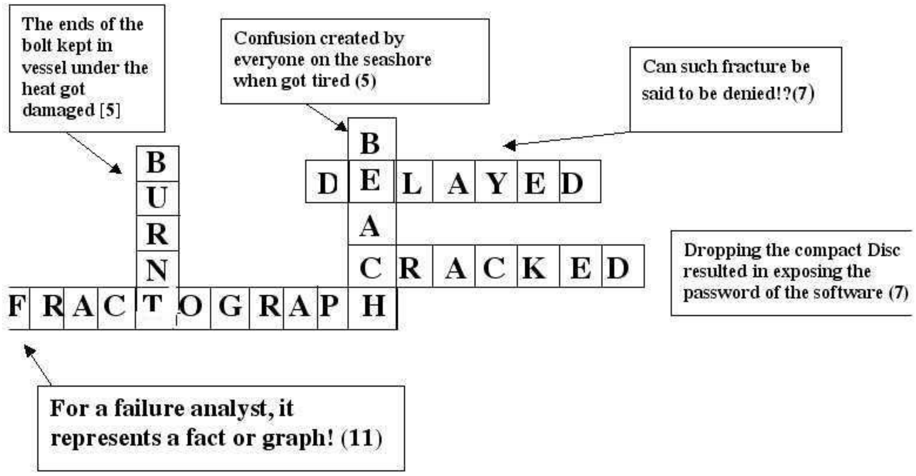

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