Issue 13

February 2015

SFA

Message from our President

Dear Friends and colleagues,

Very nice to meet you all again through this column. Greetings to all of you.

Today, I would like to discuss with you an important branch of engineering known as the Reliability Engineering (RE). Human being first stepped into the realm of RE when he successfully employed an ancient pump, the Noria, the first sophisticated man-made machine to transfer water to troughs, viaducts and other distribution devices to irrigate fields and provide water to communities utilizing hydraulic energy from the flow of a river or stream. If the community Noria failed, the people who depended upon it for their supply of food were at risk. Thus, survival was the genesis of motivation for reliability and dependability. Reliability, thus, is a quantitative measure of the integrity of a designed part, component, product, or system. Dependability, or reliability, describes the ability of a system or component to function under stated conditions for a specified period of time. Reliability is theoretically defined as the probability of success (Reliability = 1 - Probability of Failure). An engineering discipline which emphasizes dependability in the lifecycle management of a product is known as RE. Maintainability and maintenance are an integral part of RE in Reliability Programs which play a vital role in the cost-effectiveness of systems.

Reliability risk is assessed using reliability hazard analysis, failure mode and effects analysis (FMEA), fault tree analysis (FTA), Reliability Centered Maintenance (RCM), material stress and wear calculations, fatigue and creep analysis, human error analysis, reliability testing, etc. The basic steps involved in reliability risk assessment are, 1) identification of potential causes/factors which fall into the arena of unreliability e.g. human errors, failure modes, root causes etc. using specific tests and analysis, 2) assessment of the associated system risk by specific analysis or testing, 3) proposing mitigation and lowering risk to an acceptable level through design changes, detection logic, maintenance, training, 4) determination of the best mitigation process and final agreement about the acceptable risk levels, possibly based on cost-benefit analysis. Generally, a reliability program plan (RPP) is defined for projects, which specifies the reliability tasks to be performed, due to the involvement of multitude of reliability techniques and their expenses.

No industry in any country can progress effectively without the knowledge and implementation of RE. Today RE has developed to a higher degree of refinement and quantification. All countries ought to seize upon the opportunity to enlighten their scientists, engineers and industrial as well as government personnel about the merits of this field. Such personnel should enhance their technical and industrial progress by learning the principles of RE and by applying these principles in their daily efforts. The success of RE lies in its actual application to the practical situations.

A former United States Secretary of Defense, economist James R. Schlesinger, aptly stated: "Reliability is, after all, engineering in its most practical form."

I wish you all success in your endeavours

Best wishes to all the readers!

T. Jayakumar

Welcome you all to join as members of SFA! Please find the membership form inside; kindly fill in and contact Secretary of SFA through email.

Experts and experiences:

Dr.Nayak, BARC, Mumbai

Prof.Chandrasekaran, IIT, Madras

From the Desk of Editors

Warm greetings! We are happy to present you the thirteenth issue of the newsletter of Society for Failure Analysis (SFA).

We are happy to inform you that SFA, Bangalore and Hyderabad chapters conducted one day events which received excellent participation and support of industries. These efforts have really yielded fruits. We provide a glimpse of the programs conducted at these places in this issue as reports.

We have solicited articles from experts in the important area- reliability and protection of structures serving in sea.

We thank the authors for their contributions which are truly significant as far as SFA is concerned.

We take this opportunity to appeal to the Indian industry to use SFA as a forum to share their experiences on trouble shooting. 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 along with; the books recently published on the topics of the subject.

We value your comments, which really boost our enthusiasm to perform better. Therefore, as always, your views and comments, mailed to pujar@igcar.gov.in or param@igcar.gov.in are welcome. We wish you all free from failures and a joyful life!

You may visit our web site for your comments/suggestions or any queries : www.sfaindia.org

Kalpakkam (M G Pujar)
28-02-2015 (P .Parameswaran)
Editors

We encourage you to join the society, Kindly fill up the application form (enclosed at the end of the newsletter) and contact secretary:, post your application with draft to Dr.N.Eswara Prasad, Regional Director, ***RCMA,*** *CEMILAC, Kanchanbagh, Hyderabad, 500 058*

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

National seminar on "Failure Analysis of Aero-Materials, Components & Systems (FAAMCS-2014)

Society for Failure Analysis (SFA) Bangalore Chapter jointly with CEMILAC (Centre for Military Airworthiness and Certification), Regional Centre for Military Airworthiness (F&F-FOL), Bangalore and Hindustan Aeronautics Limited (F&F), Bangalore complex, conducted a "National Seminar on Failure Analysis of Aero-Materials, Components and Systems: FAAMCS-2014" on 10/10/2014 at CEMILAC auditorium.

Dr. C. P. Ramanarayanan, OS & Director, GTRE, Bangalore felicitated the occasion as Chief Guest. Prof. Vikram Jayaram, IISc Bangalore delivered the key note address. Shri D K Venkatesh, GM, HAL(F&F) spoke on need for failure analysis of aero materials and components. Shri P Jayapal, Vice president, SFA and CE(A), CEMILAC appraised the gathering on the functioning of SFA and about its effective utilization by the engineers, technologists, scientists and others. Shri G Gouda, Sc 'G' Chairman, SFA Bangalore Chapter and Group Director (Propulsion) spoke about the objective of the seminar.

Six invited talks were delivered by the eminent experts covering the entire spectrum of seminar theme involving design, composites failure, accident investigation, NDT techniques etc. Shri M S Velpari, AGM (Mfg), HAL (F&F), Convener, FAAMCS-2014 and Secretary, SFA Bangalore chapter welcomed the gathering. Dr. Shirish S Kale, Convener, FAAMCS-2014, Joint Secretary, SFA Bangalore chapter and Regional Director, RCMA (F&F-FOL), delivered the vote of thanks. 134 delegates from all over India participated in the seminar actively and got benefitted.

"Failure Analysis in industry" by SFA, Hyderabad chapter and Nuclear Fuel Complex, Hyderabad

Workshop on "Failure Analysis in industry" was organized by SFA, Hyderabad chapter alongwith Nuclear Fuel Complex, Hyderabad on 20th January, 2015. The event began with a welcome address by Dr.Komal Kapoor, SO/H and Head, Quality Assurance, NFC. Then on behalf of SFA head office, Dr Eswara Prasad briefed the audience about the various activities of the Society. Followed by this, the workshop was inaugurated by Dr. N.Saibaba, Distinguished Scientist and Chief Managing Director of NFC who further continued with a key note address enunciating the importance of failure analysis for any industry for successful production with sustained gains through excellent deliberations citing examples from NFC's experiences. The second lecture was delivered by Dr. K.P.Balan, Scientist, DMRL, Hyderabad bringing out the systematic metallurgical analysis based on his experiences, having carried out more than 400 case studies. This was followed by a lecture by Dr. Kulvir Singh, Corporate R&D, BHEL, Hyderabad who shared his vast experiences in studying "Creep Failures in Power Plant Components". This was followed by an exemplary lecture on the dynamics of defects in materials and their interaction, behavior etc by Sri.A.K.Jha, VSSC, Thiruvananthapuram. The post lunch session witnessed three more lectures with Dr.Vivekanand Kain, SO/H+, BARC, Mumbai discussing the effect of harsh environment on the corrosion attack of power plant components with special emphasis on flow induced corrosion in the pipes of nuclear reactors. This was followed by a lecture on Failures in Weldments by Dr Madhusoodhan Reddy, Scientist, DMRL, Hyderabad who brought out distinct cases of possible failures caused by defects generated by complex solidification experienced in welds. The final lecture of the day was delivered by Dr P.Parameswaran, SO/G, IGCAR, Kalpakkam who brought out importance of quality control and monitoring in materials as a feedback to choice of materials, production routes and service fluids for sustaining failure- free service lives. The valedictory function was graced by the eminent failure analyst of the country, Dr Reddy, Past president, SFA who alongwith panel members discussed and answered many useful querries from the audience which was represented by personnel from several industries, a few academic institution and NFC. The vote of thanks was delivered by Joint Secretary who expressed NFC, Hyderabad for supporting the event, industries who sponsored the lunch etc.

Dr.N Eswara Prasad briefing the delegates about SFA ; seated (L to R) are: DR Komal Kapoor, Convener of the event, Dr.Kamat Shetty, Chairman SFA, Hyderabad Chapter and Dr.N.Saibaba, CMD, NFC, Hyderabad

Reliability Assessment of Passive Safety Systems: Accomplishments and Unresolved Issues

Dr.A.K. Nayak

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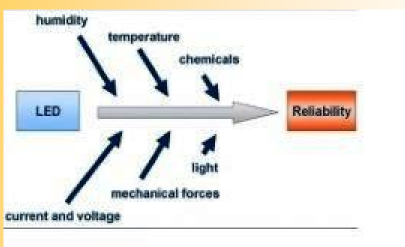
Considering the need for a larger scale of deployment of nuclear power in future and to eliminate the concerns in public mind about the safety of nuclear power plants, the safety goals for the new nuclear power plants are sought to be further enhanced. The International Nuclear Safety Group (INSAG-12) and INPRO has set the targets of Core Damage Frequency (CDF) of not more than 10^{-5} /reactor year for future nuclear power plants in comparison to the present goal of 10^{-4} for existing plants. The goal for the Large Early Release Frequency (LERF) has been enhanced further to 10^{-6} /reactor year in place of present goal of 10^{-5}/reactor year. The currently operating reactors have extensively used **"active engineering safety systems"** for reactor control and protection. One of the major problems with active safety systems is that the reliability of these systems cannot be improved beyond a threshold. In addition, these systems are prone to the errors made by operator's actions and their subjective decisions. Passive systems, on the other hand, are believed to be more reliable than the active safety systems and hence, can provide enhanced protection against any postulated accidents. This is because passive systems do not need human intervention or require external energy sources such as electricity or pneumatic supply for their operation.

IAEA defines the passive safety system as "A system which is composed entirely of passive components and structures or a system which uses active components in a very limited way to initiate subsequent passive operation". Many of the advanced reactors e.g. ESBWR, AP1000, CAREM, AHWR, etc. incorporate several passive systems in the design of the reactors. The major benefits arising from the use of passive systems are: a) absence of active systems like pumps; b) simple in design, easy to build, operate and maintain; d) enhancement in safety and reliability as compared to the active system, leading to reduction in offsite emergency planning; e) reduction in human interventions resulting in fewer potentially unsafe actions; and f) increased operability and capacity factor.

Despite the above, there are technological challenges and issues in order to engineer them in the reactor designs. One of the issues with the passive systems is accurate quantification of functional reliability for these systems during normal operation and transients including accidental conditions. These functional failures are the type of failures, which happens because of deviations in boundary conditions of the critical process or geometric parameters on which passive systems performance depends. The main difficulties in evaluation of functional failure of passive systems arise because of: a) lack of Plant Data and Operational Experience; b) lack of sufficient experimental data from Integral Facilities or even from Separate effect Tests in order to understand their performance characteristics not only at normal operation but also during transients and accidents; c) the definitions of failure mode of the systems are not well defined; and d) difficulty in modeling the physical behavior of such systems.

A historical perspective to this topic reveals that first methodology aimed to evaluate the reliability of passive systems was Reliability Evaluation of Passive Safety System (REPAS). REPAS methodology was a joint effort of UNIPI, ENEA, University of Rome and Polytechnic of Milan. In REPAS, failure probability of passive system was evaluated by propagating the epistemic uncertainties of important physical and geometric parameters which affects the system performance the most. REPAS methodology is based on the evaluation of a failure probability of a system to carry out the desired function from the epistemic uncertainties of those physical and geometric parameters which can cause a



failure of the system. REPAS methodology recognizes model uncertainties of the codes. However, it was later identified that to assess the impact of uncertainties on the predicted performance of the passive system, a large number of calculations with best estimate codes were needed.

REPAS methodology was embedded in the Reliability Methods for Passive Safety (RMPS) methodology, developed within the framework of a project called RMPS, under the European 5th Framework program. RMPS method considered the identification and quantification of uncertainties of variables and their propagation in thermal hydraulic models, and assessment of thermal hydraulic passive system reliability. In RMPS, the passive system is modelled by a qualified T-H code (e.g. CATHARE, RELAP) and the reliability evaluation is based on results of code runs, whose inputs are sampled by Monte- Carlo (M-C) simulation. In order to limit the number of T-H code runs required by M-C simulation, alternative methods have been proposed such as variance reduction techniques, first and second order reliability methods and response surface methods. The RMPS methodology has been applied to passive systems utilizing natural circulation in different types of water cooled reactors.

A different methodology called Analysis of Passive Systems ReliAbility (APSRA) was developed in the year 2007 in BARC. Unlike RMPS, in APSRA methodology, it is attributed that the deviations of input parameters on which passive system performance depends, occur because of malfunction or failure of mechanical components. In APSRA methodology, first a failure surface is generated by considering the deviations of all those critical parameters, which influence the system performance. These failure surfaces are generated by evaluating the effect of these deviations on passive system performance using qualified T-H codes (e.g. RELAP, CATHARE etc.). Then root cause analysis is performed to find the cause of these deviations. Once the causes of these deviations are determined, the failure probabilities of these causes are obtained from generic data values as well as from plant operational experience data. Finally, the failure probability of passive system is evaluated using classical PSA techniques like fault tree analysis. The top event for the fault tree is considered as passive system functional failures (for example, passive system unable to maintain the clad temperature below certain threshold) and the basic events are malfunctioning or failed component states. To reduce the uncertainty in code predictions, APSRA methodology suggests relying on experimental data from integral test facilities as well as from separate effect tests. Apart from RMPS and APSRA methodologies, a few alternative approaches have been investigated in the area of reliability assessment of passive systems. This includes approaches developed at ENEA.

The above methodologies REPAS, RMPS and APSRA have uncovered very important aspects related to passive safety system reliability. Among the noticeable accomplishments of these methodologies are: a) an agreed definition of reliability of passive system; b) it has been accepted by all the methodologies that passive system performance and reliability are functions of boundary conditions, their deviations from designed nominal conditions could affect the performance and hence reliability; c) it is accepted that input parameters and boundary conditions vary between some limits, some of these parameters and boundary conditions are critical for passive system performance; and d) in all the methods, defining failure of passive system is given the prime importance and it can be concluded that most of them have defined it as either fail to meet the amount of heat exchanged or to keep maximal clad temperature in a safe range during the operation.

Present methodologies lack to explain

some of the important issues related to passive systems performance and reliability analysis. Some of these unresolved issues are:

Applicability of best estimate codes and model uncertainty: One important unresolved issue is the applicability of the best estimate codes such as RELAP5 or TRACE or CATHARE, etc for passive systems and propagation of model uncertainties in code calculations. Of course, these codes have been validated over several years using test data from separate effect facilities and integral experiments and it is now well recognized that they are acceptable for active systems. However, to use these best estimate codes for performance analysis and failure of passive systems is doubtful. There could be large-scale uncertainties in simulation of several phenomena of these systems, particularly: a) natural circulation flow instabilities and heat transfer; b) condensation in presence of non-condensables; c) critical heat flux under oscillatory condition; and d) thermal stratification in large pools. The uncertainty in these predictions could be only reduced by verifying the codes for different passive systems and relying more on experimental data. Treatment of the residual uncertainties (e.g. scaling uncertainties) when code validation data are available is an important future task as well.

Treatment of dynamic failure characteristics of components: The methods implemented so far for reliability assessment of passive systems do not consider dynamic failure of components or process. In RMPS, variation of process parameters is considered through a pdf treatment. These pdfs are assumed to be invariant in time. In actual, the parameters variation from their nominal values could be time dependent. APSRA relies in calculating failure probabilities of components for treatment of variation of process parameters through classical fault tree and event tree. These methods only consider binary states of any component failure i.e. failure or success states; however, the components like mechanical, electrical, instruments and control systems may fail in intermediate states. Examples of such components are control valves and relief valves, etc. Some components do not directly fail; they fail after some considerable amount of time while degradation of function is taking place during accident progression or otherwise. It may so happen that while one component is failing, it accelerates or induces some other component failure which in turn may lead to system failure much before it is predicted. In view of this, there is a need of dynamic reliability analysis which considers the evolution of process variable and their effects on component failure rates in reliability analysis.

Treatment of independent process parameters variations in passive system reliability analysis: Broadly, the parameters affecting passive system performance can be classified into two types: (a) dependent parameters and (b) independent parameters. Dependent parameters are the ones whose deviations depend upon the output or state of certain hardware or control units, example of such dependent parameters are pressure, sub-cooling, non-condensable gas. Many of dependent parameters are not independent to have their own deviations; rather they are correlated or interdependent. Independent parameters are the ones whose deviations do not depend upon certain components rather they have their own patterns and deviations which cannot be predicted easily; example of such parameter is atmospheric temperature. The dependence of system performance on these types of parameter is quite significant in many passive systems for example passive decay heat removal system. Performance of these systems is very sensitive to the water inlet temperature (sink temperature) or atmospheric temperature or the environment temperature. These parameters vary in time due to their evolution along the mission period of system operation. Environment temperature has certain pattern depending on the season and time of operation (day/night) and some random variations on that; so it cannot be called as an uncertain parameter and treated by a random probability distribution between minimum and maximum for the analysis purpose. To resolve the uncertainties in the reliability calculations because of assumptions around the parameters like atmospheric temperature, one has to build the models of such parameters from the data that has been continuously monitored around the applications of passive systems. These parameters could be given as real-time data into the simulations once the models are built. In summary, while advanced reactor concepts propose to adopt passive safety systems which definitely have potential to enhance the defence-in-depth and make nuclear power plants inherently safe even during extreme events like earthquake, tsunami and floods, however; incorporation of these systems in the nuclear reactors needs to be tested adequately due to several technical issues listed above. A few methodologies such as, REPAS, RMPS and APSRA have been developed in the past and applied to evaluate reliability of passive systems. While these methodologies have certain features in common; but they differ significantly particularly in the treatment of deviations of process parameters from their nominal values and model uncertainty in best estimate codes which are paramount for evaluation of reliability of such systems. Currently, the performance of passive systems and their failure are predicted by so called 'best estimate codes'. However, the applicability of the 'best estimate codes' to assess the performance and failure of passive systems is not well established which should be done by extensive experiments and comparison of code predictions with test data. Current methodologies lack in the treatment of dynamic failure characteristics of components of passive systems. It is also required to pay attention to the treatment of dynamic variations of independent process parameters such as atmospheric temperature in passive system reliability analysis in future. The author recommends more research to be targeted in these fields in near future.

Obituary

Shri K.V. Kasiviswanathan, a doyen in the field of inspection technology and failure analysis passed away on 26 August. 2014. He had served Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam more than 34 years. Before superannuation as an Outstanding Scientist (OS) and Associate Director (AD), Group for Robotics and Remote Handling, In-service Inspection & Post Irradiation Examination (GRIP), Metallurgy and Materials Group (MMG), IGCAR. He was continuing as Raja Ramanna Fellowship until his demise.

Shri K.V. Kasiviswanathan was a specialist in the multidisciplinary areas of Post Irradiation Examination (PIE) of fast reactor core materials, metallurgical failure analysis, development of remote handling and robotic devices for applications in different fuel cycle activities, non-destructive evaluation (NDE) and mechanical testing of small specimens.

He made exemplary contribution to GRIP by setting up an unique inert atmosphere hot cell facility for metallurgical examination of irradiated nuclear fuels and structural materials with a variety of indigenous in-cell components for non-destructive and destructive examinations. Shri Kasiviswanathan and his team successfully conducted PIE campaigns for Fast Breeder Test Reactor (FBTR) core materials which include the mixed carbide fuel, structural materials, control rod as well as determination of mixed oxide fuel for Prototype Fast Breeder Reactor (PFBR). Thus his contributions in PIE facilitated prediction of the residual life of FBTR fuel and structural materials which ensured safe operation of the reactor, during fuel handling, PIE and subsequent tests.

He formed a team of engineers for investigating metallurgical failures of critical engineering components in nuclear, aero space, petrochemical and process industries. He led a number of failure investigations including those of critical components such as Low Pressure (LP) steam turbine blades, boiler heat exchanger tubes, end shield material from various nuclear power stations and many critical components in the sodium circuits of FBTR as well as aero-engine turbine blades and air-craft structural materials.

He played a key role in initiating novel mechanical test methods using miniature specimens. He nurtured and guided a team of engineers and scientists towards standardising/benchmarking the techniques for evolving a common code of practice in these areas. He also initiated finite element methods (FEM) based modelling works for a better understanding of the mechanical behaviour of miniature specimens. He was involved in developing field equipments based on indentation tests for residual life assessment (RLA) of engineering components in power plants. He made significant accomplishment in the field of remote handling, automation and robotics, developing a number of indigenous automation and remote handling tools and equipment for the plant being set up for remote fuel fabrication and reprocessing facility. He was member of leading professional bodies such as Indian Nuclear Society (INS), Indian Institute of Metals (IIM), Institution of Engineers (I), Indian Society for Non-Destructive Testing, Neutron Radiography Working Group and Acoustic Emission Working Group. His wide-ranging interests and accomplishments brought him recognition in the form of various awards and honours as follows:

- NUCOR Award for best technical paper from Indian Institute of Welding (1991),
- KCP Award for best Technical paper from Indian Institute of Welding (1991),
- SAIL Gold medal from Indian Institute of Metals, best paper in Trans. IIM (1998),
- Best paper award, Industrial Category, Indian Society for NDT (1998),
- National NDT Award for System Innovation & Development, Indian Society for NDT (1999)
- Group Achievement Award for Scientific &Technical Excellence from DAE (2008)

SFA salutes this noble soul and acknowledges his significant and meaningful contributions in the diverse fields of Metallurgy and Materials Engineering in general and NDT and PIE in particular and prays God for granting him eternal peace.

RETROFFITTING OF OFFSHORE STRUCTURAL MEMBER USING PERFORATED CYLINDERS

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Introduction

Offshore structures are designed to ensure survival even under the extreme load combinations. Deployment of compliant structures in deep sea necessitated research methods that shall reduce the encountered wave and wind forces. Use of perforated components/parts in offshore structures is one of the possible solutions for retrofitting and rehabilitation of the structures. Emerged and submerged perforated cylindrical structures reduce wave-structure interactions considerably, but their use on compliant offshore structures is limited. Retrofitting and rehabilitation is usually related to strengthening of partial structures, the concept presentedhere is a novel attempt as it addresses reduction in the forces of interaction with the members. Presence of perforated members in ocean structures reduces the wave-structure interaction significantly; breakwaters with perforated members are classical examples of such kind. This concept of encompassing the perforated outer cylinder with inner (existing) structure is found to be the most economical and feasible way of rehabilitation as it does not demand any replacement of damaged components/parts. The presence of outer perforated cover alters the water particle kinematics significantly and eventually this remains the reason for the force reduction mechanism. Encompassing the members with a perforated outer cover will not only enhance their service life but also reduce the hydrodynamic forces caused by the direct wave impact [1]. Significant reduction is seen in the hydrodynamic forces experienced by the inner cylinder, which is encompassed by semi-porous cylindrical breakwater [2]. Srinivasan and Parameswara[3] quantified the force reduction on inner cylinders encompassed by perforated outer cylinders through experimental investigations. Srinivasan et al.[4] showed that there was significant reductionin forcestothe extent of ~ 60% on the inner cylindrical structure when encompassed by perforated outer cover. Influence of perforation ratio and the size of perforations on response reduction are highlighted in this paper. Srinivasan and Madhavi[5-7] quantified the variation of water particle kinematics along the depth of cylinder when the component/partwas encompassed by the perforated outer cover. Similar studies are carried out by Zhong and Wang [8], Zhao et al. [9], Song and Tao [10] andSarpakaya and Isaacson [11].

Experimental Setup

Scaled model of three sets of PVC cylinders with the outer and the inner diameters of 315 and 115 mm respectively were experimentally investigated to study the effect of perforation and the diameter of the perforation on the force reduction. Diameter of the perforations and the perforation ratio were varied appropriately. Steel frames consisting of ISMC channels and angles were used for clamping the inner cylinder and the outer cylinder on a single rigid frame as shown in Fig. 1.

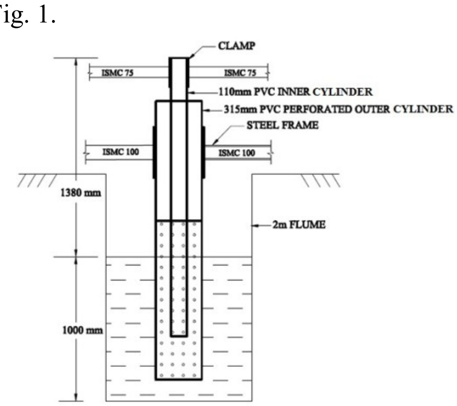


Fig. 1: Arrangement of cylinders for experimental investigation

Strain gauges were placed along the inner cylinder to determine the forces acting on the cylinder during passage of waves. Figure 2 shows the tested models of both the inner and outer cylinders with different perforation ratios respectively.

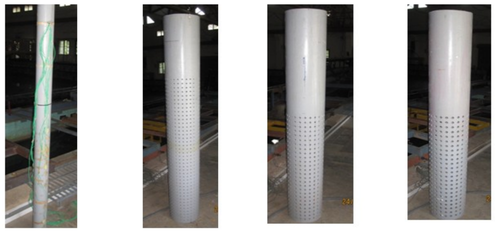


Fig. 2 perforated cylinders used in the present studies:i) inner cylinder; ii) outer cylinder (A); iii) Outer cylinder (B); iv) Outer cylinder (C)

Bending strain in the inner cylinder with and without perforated outer cylinder was measured during the passage of regular waves. Regular waves with wave height 10 cm was generated while wave periods were varied from 1 s to 2 s with an interval of 0.2s. Figure 3 shows the a representative value for bending stain variation in inner cylinder without outer cylinder for wave height and wave period to be 10cm and 1sec.

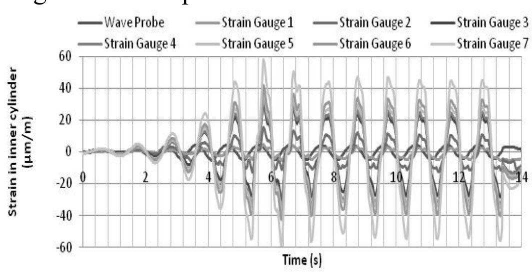
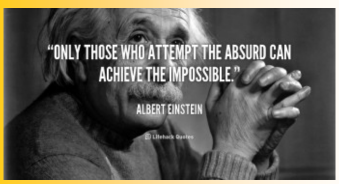


Fig. 3 Bending strain variation in inner cylinder without outer cylinder(WH = 10 cm; WP = 1 s)

It was observed from the above table that there was significant reduction in the forces on the inner cylinder in the presence of perforated outer cylinder. Presence of outer cylinder A, B and C resulted in reduction of forces up to63.10%, 37% and 29.57% for 1 s wave period and 53.83%, 41.35%, 19.78% for 2 s wave period for a wave height of 10 cm. The variation in nonlinear; reduction in wave forces experienced by inner cylinder, in the presence of perforated outer cylinder was significant in comparison to the case without perforated outer cylinder. It was also observed that forces on inner cylinder increased with the increase in perforation ratio and decreased with the decrease in perforation size. The variation of force on the inner cylinder is shown in Fig. 4.



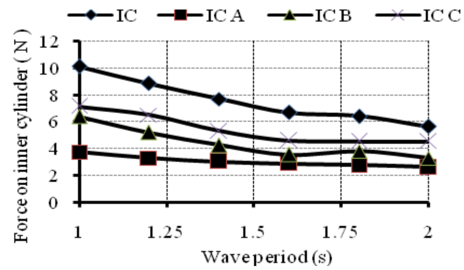


Fig. 4: Force variation on inner cylinder with perforated outer cylinder(WH = 10 cm)

Acknowledgments

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Society for Failure Analysis

Application Form

Society for Failure Analysis
C/O Centre for Military Airworthiness & certification, RCMA (Materials)
Hyderabad500 058

Phone: 040-24340750; 24348377;
Fax : 040-24341827
E-mail: rdrcma.mat@cemilac.drdo.in

Affix a passport size photograph

Please √ applicable **member** ☐ **Life Member** ☐

First Middle Last

2. **Date of birth**
3. **Father's Name/ Husband's Name**

4 **Present Occupation /Designation and office address:**	**Phone:** **Mobile:** **Fax:** **Email:**

5 **Academic & Professional Qualifications**:

6 **Home address:**	Phone: Mobile: Fax: E-mail

6. **Address for correspondence:** **office** ☐ **Home** ☐

7. **Professional Experience**:
8. **Endorsement by SFA Member**

Name	Membership No.	Signature

9. **Primary Field of Interest: (please mark 1,2,3 in the in order of preference**)

Strategic ☐	**Power** ☐	**Foundry** ☐	**Welding** ☐	**Heavy industry** ☐	**transport** ☐
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10. **Name of the Chapter you intend to be attached**______________________________
(Please refer to Chapters' list)

11. **Subscription details:**
Payment should be made by cheque / DD favoring **"Society for Failure Analysis"**, payable at Hyderabad. Outstation cheques not accepted.

Amount Rs. Cheque / D.D. No Dated

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Category	Amount Payable		
	Admission Fee (One time)	Yearly Subscription	Total on joining
Member	---	Rs.200 (annual)	
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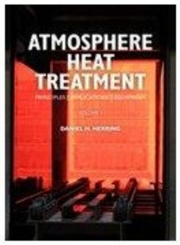
12 **Declaration by the applicant**
If elected, I agree to accept to pay the prescribed yearly subscription, to abide by the Articles of Association of the Society and to promote its aims and objects.
Signature of the Applicant

13.	**Office Use Only**				
	Membership No.		Date of Enrolment	Chapter	
	Amount Paid (Rs)		Receipt No. / Date		

Books/ new journals/ news about our members



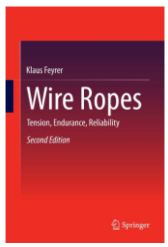
Atmosphere Heat Treatment: Principles, Applications, Equipment - Vol. 1

Price: $154.99

Author: Daniel H. Herring

Published: September 2014

This two-volume book series will make available a comprehensive resource on atmosphere heat treatment and will provide readers with a wide range of useful information, both from a practical and technical standpoint. Readers will be able to make better and more-informed decisions about their equipment, process, and service needs. What makes this book unique to the heat-treating industry is that it is written specifically for the heat treater, engineer, and metallurgist by one of their own.



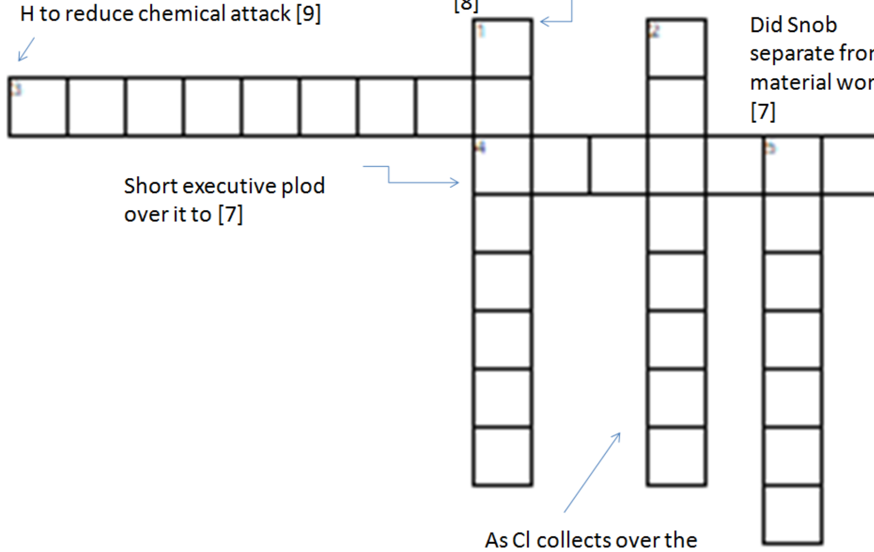
This book presents the methods used to calculate the most important parameters for ropes, explains how they are applied on the basis of numerous sample calculations. The book, based on the most important chapters of the German book DRAHTSEILE, has been updated to reflect the latest developments, with the new edition especially focusing on computational methods for wire ropes. Many new calculations and examples have also been added to facilitate the dimensioning and calculation of mechanical characteristics of wire ropes. This book offers a valuable resource for all those working with wire ropes, including construction engineers, operators and supervisors of machines and installations involving wire ropes.

Finger grips on TT racket results in frictional damage [8]

IITB develops In based solution taking H to reduce chemical attack [9]

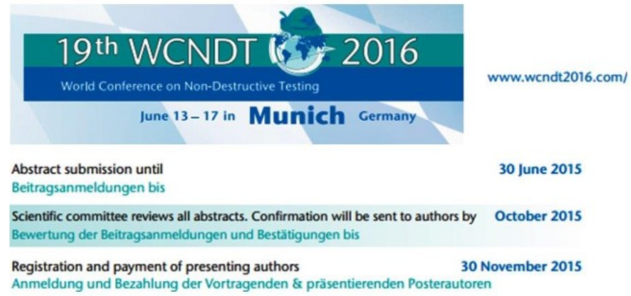
Did Snob separate from material world? [7]

Short executive plod over it to [7]



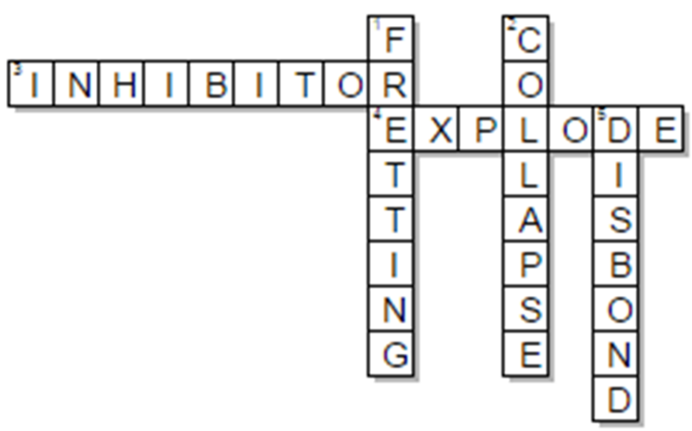
As Cl collects over the pole, latter may fall suddenly [8]

Events in the pipeline



5th International Conference on INTEGRITY-RELIABILITY-FAILURE (IRF2016), to be held in **Porto (FEUP), 24-28 July 2016**.

Answer to Cross word



Forth coming SFA events* for the current year (2014-15)

1) **Clinic on Failure Analysis (CFA-2-15) at Anna Univ., Chennai, March 5-6, 2015**
2) **Workshop on Engineering Failure Analysis- NIIST, Thiruvananthapuram, March, 2015**
3) **Workshop on Service Performance of engineering materials, IIT Rourkee, 2015.**

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