Journal of Indae
Non Destructive Testing and Evaluation

March 2022
Volume 19 • Issue 1

An Official Journal of the Indian Society for Non Destructive Testing

If Undelivered Return To :

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Module Nos.60 & 61,
Readymade Garment Complex,
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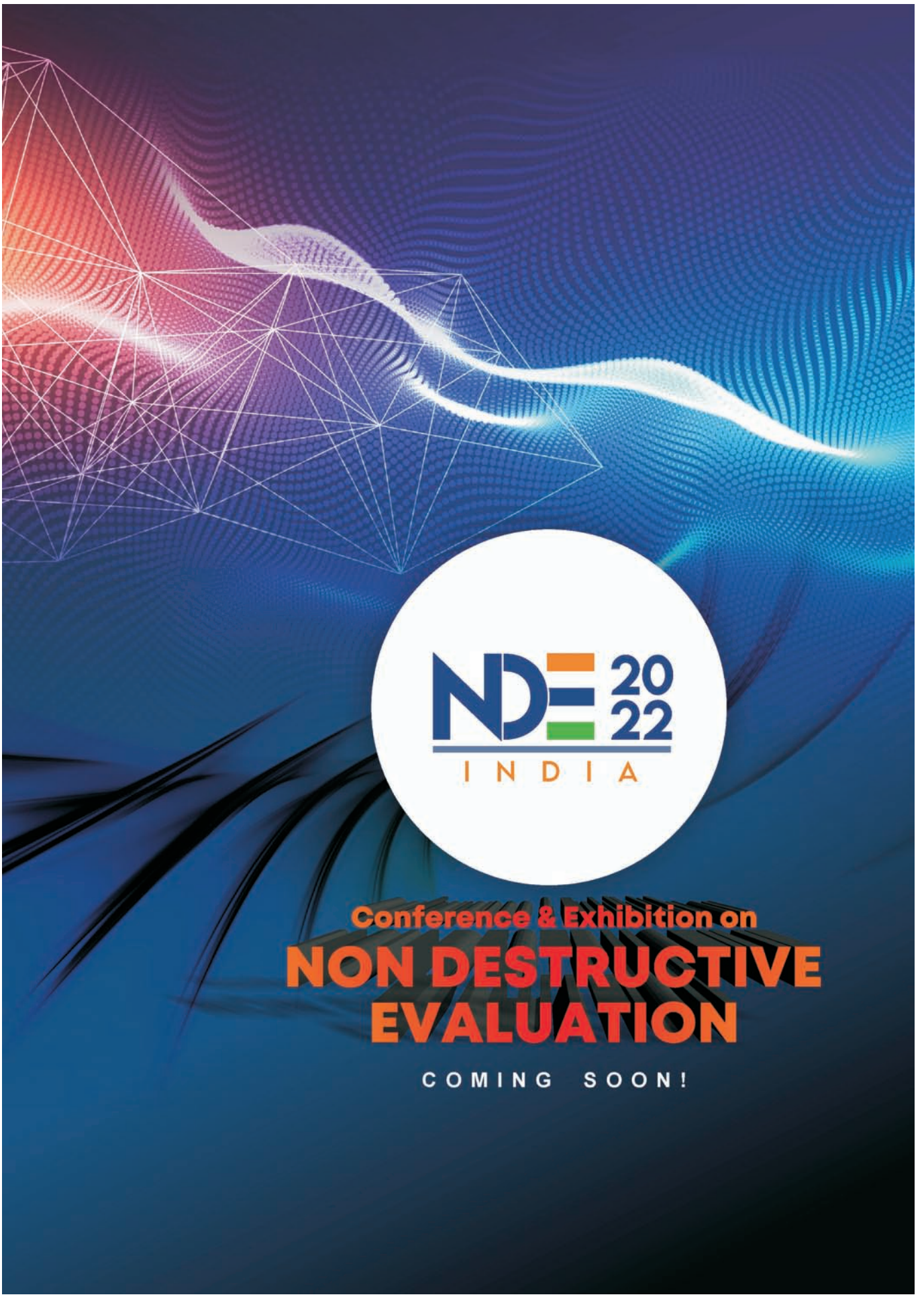
NDE 2022
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Conference & Exhibition on
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COMING SOON!

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Journal of JNDE Non Destructive Testing and Evaluation "Connecting NDT Professionals" AN ISNT PUBLICATION

MARCH 2022
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ON THE **COVER** Page

Virtual venue NDE 2021

OBJECTIVE – This Journal of Non Destructive Testing & Evaluation (JNDE) is published quarterly by the Indian Society for Non Destructive Testing (ISNT) for promoting NDT Science & Technology. The objective of this journal is to provide a forum for dissemination of knowledge in NDE & related fields. Papers will be accepted on the basis of their contribution to the growth of NDE Science & Technology.

PUBLISHED BY:- Mr. Bikash Ghose - Managing Editor, JNDE

For JNDE SUBSCRIPTION & ADVERTISEMENT
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LETTERS

PRESIDENT Talk

Diwakar Joshi
President – ISNT
president@isnt.in

I feel elated in communicating with you through this long-awaited issue of JNDE!

Yes, you must be seeing this release after a year. The long gap in this otherwise routinely published journal was painful to all of us, but we were a bit helpless in side tracking it due to other priorities in the pandemic period.

The pandemic, though, was not a deterrent in the functioning of ISNT, and we saw full-fledged operations like training and examinations, webinars and yearly seminar etc. continuing.All chapters have done excellent work during the pandemic to keep the ball rolling.

The new National Governing Council was formed and some points on the agenda are already coming to fruition. The Training Management Board is now specially formed to streamline the various activities like training material generation, authorization of chapters and training institutes, and standardization of training activities all over the country.I am very happy to see that many NDT and Training experts have joined the board voluntarily and started contributing for the common goal. This goes hand in hand with the wider acceptance by the industry of ourIS 13805 and ICN scheme (ISO 9712) for certification of NDT personnel.National Certification Board is also gearing up to take on the increased load and demand from the industry.

ISNT will soon be completing its 50 years from the inception. The successful journey in these 50 years is the result of passionate and dedicated work by all past presidents and their teams. Coincidently this also matches with the 75th anniversary of India's independence. I appeal all of you to contribute whole-heartedly in making ISNT a global society.

We are seeing some good signs of lifting of all restrictions step by step, which will give us a further boost in working more efficiently. I am sure that in future the periodicity of the journal will be well maintained.JNDE is the most effective medium of our lateral communication, learning, sharing and progressing technology.

I appreciate the hard work put in by H.O. and JNDE team in bringing the Journal on track again and releasing this issue.

I wish JNDE a bright future and a mass international acceptance, which I am sure is on the way!

Diwakar D. Joshi
President

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Magnetic Particle

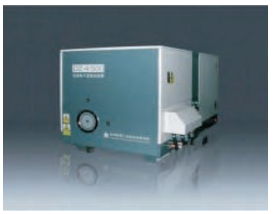
- Prod Units
- Yokes
- Bench Units
- Ultraviolet Black Light
- Consumables & Essentials



Radiography

- Gamma Ray Projectors
- IR-192,Se-75, Co-60 Sources
- Linear Accelerator
- Digital Radiography
- Radiation Detection & Monitoring Devices



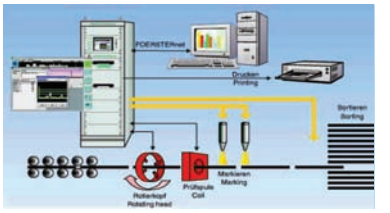



Ultrasonic Systems

- On Line / Off Line Systems
- Bar Testing
- Pipe Testing
- Piston Testing
- Component Testing


Eddy Current

- Sorting Equipments
- Component Testing Equipments
- Material Testing Equipments
- Portable Instruments

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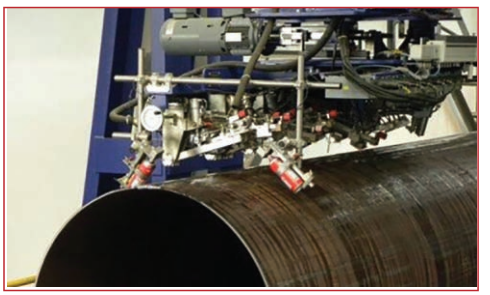

Ultrasonic Systems

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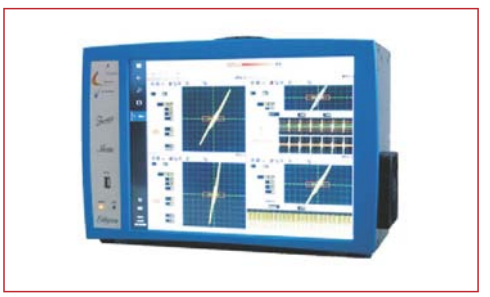

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ABOUT ISNT

Indian Society For Non Destructive Testing (ISNT) was formed on 21st April 1989 by merger of two societies namely Non Destructive Testing Society of India registered in Calcutta in July 1972 and Non Destructive Inspection Engineering registered at Madras in March 1981. It is a non-profit organization and is registered under the Tamil Nadu Societies, Registration Act, 1975 (Tamil Nadu Act 27 of 1975) Regd. No.49 of 1981.

The Indian Society for Non-destructive Testing (ISNT) is the society for NDT professionals and practitioners which offers invaluable resources, information and linkages for industrial quality development and professional development to its members. The objective of the Society is to promote the awareness of NDT Science and Technology through education, research and exchange of technical information within the country and internationally to its members and other professionals using NDT. The family of ISNT has more than 6000 strong members. It is a diverse and dynamic family of professionals representing NDT technicians, scientists, engineers, researchers, manufacturers and academicians – all dedicated to improve product safety and reliability. These specialists represent virtually every industry and discipline that may benefit from NDT technology.

ISNT holds periodic seminars and workshops on topics relating to NDT methods and applications, as well as exhibitions displaying cutting edge NDT products and services.

ISNT has 19 chapters spread all over the country with headquarters at Chennai. In addition to the above, we have two wings.

• **National Certification Board** - The National Certification Board has been formed for the training and certification of NDT professionals in India and has been periodically conducting Level-I and Level-II courses through ISNT chapters. NCB-ISNT has been recognized by ASNT as the NSO in India and has been periodically conducting Level III ASNT exams right from 1986. NCB-ISNT plays key role in international harmonization of training and certification.

• **QUNEST – Quality Through Non-Destructive Evaluation Science and Technology** - The QUNEST trust has been formed to : a) Identify NDE issues and thrust areas;
b) Foster NDE Science and Technology nationally with international inputs;
c) Continuing Education and
d) Enhance international standing and make ISNT a global player.

ISNT keeps the members informed about technological advances, new products, certification and training and international linkages.

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CHAPTER News FOR THE PERIOD FROM DECEMBER 2021 TO MARCH 2022

AHMEDABAD CHAPTER

Radiography Testing Level 2 course was conducted from 07-02-2022 to 15-02-2022. Exam was conducted on 17th &18th February, 2022. Number of candidates attended was 13

Photographs RT II Training Programme by ISNT Ahmedabad Chapter

CHENNAI CHAPTER

COURSES CONDUCTED DURING DECEMBER 2021 TO FEBRUARY 2022

S. No	Name of the course	From	To	Course Director S/Shri	No of participants		Examiner S/Shri
					Course	Exam	
1.	UT Level-II (UT-2111)	08.12.21	18.12.21	P. Anandan	6	6	E. Sathya Srinivasan
2.	MT & PT Level-II (ST- 2110)	13.12.21	23.12.21	R. Balakrishnan	9	12	E. Sathya Srinivasan
3.	Awareness program on MT, PT, ET, RTFI and UT for Veltech faculties, Avadi, Chennai	3,4,6,7,13,14 and 15.12.2021 7,8,11,12,13, 24 and 25.01.2022		R. Balakrishnan	10	16	
	VT Level-II (VT-2112)	17.01.22	20.01.21	R. Balakrishnan	7		
	UT Level-II (UT-2113)	07.02.22	18.02.22		4	6	

EC Meetings

EC Meeting was held on 19th December 2021 by hybrid mode. 20 Members attended physically and virtually.

Newsletter

3rd E-Newsletter – Sound Bytes were released on 1st December 2021

CHAPTER FUTURE PLANS

RT Level-II course and exam from 23rd February 2022 to 6th March 2022.

4th E-Newsletter – Sound Bytes March 2022 issue will be released on 1st March 2022

CHAPTER SPACE

CHAPTER News FOR THE PERIOD FROM DECEMBER 2021 TO MARCH 2022

COURSE CALENDAR FOR 2022-2023 will be released during March 2022

Meeting with VC of Anna University

17.09.21 was a golden day for your chapter as a few prominent members could meet the new VC of Anna University to felicitate him on his appointment and chalk out a new path for the benefit of the student community.

Veltech – course participants

KALPAKKAM CHAPTER

Indian Society for Non-destructive Testing (ISNT), Kalpakkam chapter in association with Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam conducted Level II certification course in Radiographic Film Interpretation (RFI) certification in accordance with IS 13805 requirements during 17th – 21st January 2022 at Kalpakkam. Theory (General & Specific) and Practical examination were administered by NCB on 22nd January 2022.

CHAPTER News FOR THE PERIOD FROM DECEMBER 2021 TO MARCH 2022

Totally 20 Candidates from various organizations such as IGCAR, BARC(F), NPCIL, BHAVINI and other private companies have attended the programme. 11 Candidates have successfully cleared the examination.

KOLKATA CHAPTER

EC meeting held on 02-02-2022.

ULTRASONIC TESTING LEVEL II, IS 13805 conducted from 8th march 2022.

MUMBAI

Eddy Current Testing II course was conducted for IXAR from 04th Jan – 10th Jan, 2022.

Examination was conducted on 11th Jan, 2022. No of Candidates –7.

BASIC III course was conducted virtually from 10th Jan – 17th Jan, 2022.

Examination was conducted on 18th Jan, 2022. No of candidates - 10

UT II Additional Training course was conducted at ISNT Mumbai premises for TCR Engineering services Pvt. Ltd. from 26th Jan - 27th Jan ,2022. Examination was conducted on 29th Jan,2022

No of Candidates – 4.

ISNT Industrial forum (Manf. & TPI) held on 29th Jan, 2022 virtually.

PUNE CHAPTER

Virtual Programme : Interpretation of Weld and Casting Radiographs – As per ASME requirements conducted on 23.02.2022. – Total 16 Nos. of Participants were attended the same from all over India.

Short EC meeting Conducted on dated 26.11.2021 for Office Bearers.

EC meeting No. 1 Conducted on dated 01.12.2021

EC meeting No. 2 Conducted on dated 25.12.2021

EC meeting No. 3 Conducted on dated 15.01.2022

THIRUVANANTHAPURAM CHAPTER

Technical Talk on "Advancements in Materials characterization with special reference to Aerospace materials"By Dr. C V S Kiran, Lead Scientist, Skyroot Aerospace Pvt. Ltd., Hyderabad, conducted on 15th January 2022 by online platform.

Released Chapter Newsletter "Image" for the period August-December 2021.

CHAPTER News FOR THE PERIOD FROM DECEMBER 2021 TO MARCH 2022

TIRUCHIRAPPALI CHAPTER

Sl. No.	Courses & Exam. conducted	Technical Talk	Other Activities	Remarks
1	Certification Course planned/ completed- *Refer Table-1 for details.*	NIL	The Chapter's 44th ANNUAL GENERAL BODY MEETING conducted on 26-12-2021	1. 5 (4 life time & 1 student member) added during Dec 2021 to till now. 2. GST amount details shared with HO office on 08-02-2022. 3. 5 candidates attended the NDE 2021 Virtual conference and Exhibition. 4. 10 Candidates NDE 2021 Pre Conference Tutorials. 5. Cultural programme held on 26-12-2021. 6. Accounts Audit Report sent to HO via email on 08-09-2021. 7. Detailed chapter report & presentation sent to HO via email on 15-09-2021.

Table-1

Certification Course

Sr. No.	Date/Period	Particulars	Attendees
1	16-12-2020 to 23-12-2021	Magnetic Penetrant Testing Level – II (SNT_TC_1A)	12
2	23-12-2021 to 03-01-2022	Radiographic Testing Level – II (SNT_TC_1A)	12
3	03-01-2022 to 07-01-2022	Liquid Penetrant Testing Level – II (SNT_TC_1A)	12

TARAPUR CHAPTER

During the year total 06 EC meetings was held for different activity of the chapter. Chapter has prompted the activities and total 07 new members were enrolled as a life member.

ISNT Chairman Shri N S Gulavani, Treasurer Shri V H Patil and member Shri. Jamal Akhtar was given farewell on their superannuation.

ISNT Tarapur conducted its 26th AGM on 22.11.2021 at Hotel Express Inn, Boisar. Shri Manoj Joshi, Station Director, Tarapur Atomic Power Station 1&2, Shri Subhashish Patra Station Director, Tarapur Atomic Power Station 1&2 was chief guest . Chief superintendent of Tarapur Atomic Power Station 1&2 and 3&4 and R& D center, Tarapur also present during AGM.

CHAPTER News FOR THE PERIOD FROM DECEMBER 2021 TO MARCH 2022

New executive committee taken over and Shri. Vinay Thattey elected as a Chairman, Shri. Sandeep Acharya as a Hon. Secretary.

Chapters E bulletin, 4th issue inaugurated during AGM by Shri. Manoj Joshi, Station Director, Tarapur Atomic Power Station 1&2.

Chapter conducted technical demonstration on Metal analyzer and Thermography inspection equipment's in association with M/s TII, Pune and Geekays India respectively. Both the vendors were demonstrated all the available equipment's and elaborated its application. They also presented the technical specification thru power point presentation.

LPT level II training program was held on 27.12.2021 and examination was conducted on 03.01.2022. Total 20 candidates were participated during the program and 12 candidates were successfully passed the examination.

Co-Chairman Shri. Vinay Thattey presented shawl and coconut to Shri. N S Gulavani, Chairman during farewell function at chapters office.

Co-Chairman Shri. Elongoven Mudliyar, presented memento to Shri. V H Patil, Treasurer during farewell function at chapters office

Shri. Chetan Mali , Treasurer presented memento to Shri. Jamal Akhtar, EC member during farewell function at chapters office.

Chairman Shri. Vinay Thattey welcomes to Shri. Manoj Joshi, Station Director, Tarapur Atomic Power Station 1&2,NPCIL.

Chairman Shri. Vinay Thattey welcomes to Shri. S K Mahajan, Chief Superintendent, R&D Center, Tarapur NPCIL

Co-Chairman Shri. ElongovenMudliyar, welcomes to Shri. S M Mulkalwar, Chief superintendent, Tarapur Atomic Power Station 1&2,NPCIL.

CHAPTER News FOR THE PERIOD FROM DECEMBER 2021 TO MARCH 2022

Co-Chairman shri. N.K.Roy, welcomes to Shri. Gopidas, Chief superintendent, Tarapur Atomic Power Station 3&4,NPCIL.

Shri. Manoj Joshi, Station Director addressing the gathering

Shri. Sandeep Acharya ,Hon. Secretary and Shri. Chetan Mali,Treasurer visited to stall of M/s Geekys India, Mumbai

Shri. Sandeep Acharya, Hon. Secretary and Shri. Chetan Mali, Treasurer visited to stall of M/s TII, Pune

Executive committee along with new members

Welcome to Shri. Sanjay Pradhan, Distinguished Scientist and Advisor ISNT Tarapur during LPT level II certification program

Welcome to Shri. Arvind Bhide, Lead Faculty during LPT level II certification program

Candidates during LPT level II training program

CHAPTER News FOR THE PERIOD FROM DECEMBER 2021 TO MARCH 2022

Practical demonstrations to the Candidates during LPT level II training program

Examiner Shri. Jawahar Garodia along with Shri. Chetan Mali (Left) and shri. B.M.Shinde (Right)

Candidates awarded participation certificates during felicitation program after LPT level II training by Shri. S M Mulkalwar, Chief superintendent, Tarapur Atomic Power Station 1&2,NPCIL (Right) Shri. S K Mahajan, Chief Superintendent, R&D Center, Tarapur(Left).

VADODARA CHAPTER

The 35TH Annual General Meeting of Indian Society for Non – Destructive Testing, Vadodara Chapter was held on Friday, January 7TH 2022 online at 08.15 pm.

The AGM was conducted online on Microsoft Team Software.

The incoming committee is as follows:

Shri R. Venkatasubramanian – Hon. Chairman, Shri Apurva Fanse - Hon. Vice Chairman, Shri Prashant Barodia - Hon. Vice Chairman, Shri Kashyap Bhatt - Hon. Secretary, Shri Viral Thanki - Hon. Jt. Secretary, Shri Krutik Shah - Hon. Treasurer, Smt. Hemal Thakker - Immediate Past Chairperson.

Hon. Members: - Shri Keyur Shah, Shri Nimay Ginwalla, Shri Dr. M. K. Sharma, Shri Mayank Prajapati.

Hon. Advisory Member: - Shri Prof. S. K. Agrawal, Shri Dr. K. Babapai, Shri Pro f. D. K. Basa, Shri S. Lakshminarayana, Shri N. C. Shah.

TECHNICAL PAPERS

NUMERICAL INVESTIGATION OF DEBONDING ON PIEZO-ELASTIC SYSTEM USING COUPLED FIELD ANALYSIS

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Abstract. For the past few years, along with the increasing population growth the demand for the Civil Engineering structures has increased drastically. For safety and serviceability requirement the performance of these structures must be monitored periodically. Structural Health Monitoring (SHM) provides best periodic checks for measuring or sensing the response by using different types of smart materials which responds to different parameters like stress, magnetic field, electric field, heat etc. In general, EMI signature depends on the adhesive that is used to glue the PZT patch and the host structure. Any change in adhesive material might also be a cause for the deflections in the overall signature as the stress transfer occurs through the bonding layer. This paper aims to investigate the de-bonding effect of adhesive layer on the efficiency of damage detection of PZT when bonded to structure to be monitored. The Finite element (FE) coupled analysis for smart structural system i.e for aluminium beam attached to PZT patch with adhesive bond with different de-bonding geometry. The numerical results are compared with the results of perfect bonding condition to highlight the efficiency of developed model.

Keywords: Piezoelectric patch, Sensor, bond, adhesive, Electro-mechanical impedance technique, Coupled Field Analysis

1. Introduction

Electro Mechanical Impedance (EMI) is considered to be one of the best cost effective techniques in SHM, which exhibit high damage sensitivity and high performance. During the recent past, piezoelectric patches are the most common devices that are used as high frequency mechatronics transducers for Structural health Monitoring (SHM).

The PZT transducers are easily surface-bonded to the host structure to obtain the baseline coupled admittance signature of the structure which is function of structural impedance. Due to self-sensing mechanism, when they are subjected to high frequency excitations of electric field by using impedance analyser or LCR meter and the admittance signatures obtained consists of conductance as real part and susceptance as imaginary part. This obtained baseline signature is used to compare and analyse about the existing condition of the structure and further anomalies. Any damage in the host structure will cause significant change in mechanical impedance of the structure which in turn modifies the actual admittance signatures obtained from the PZT transducer. As the PZT patch is directly bonded to the structure, the mechanical impedance of the structure correlates with the electrical impedance of the patch [1]

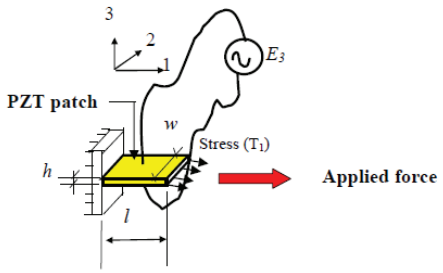

Figure. 1. EMI Technique of PZT patch

A Coupled-field analysis (CFA) is a type of analysis in which two or more than two different engineering disciplines (Fields) are combined together to solve a global problem and so it is referred as Multi-physics analyses. In much simpler terms, it can be said that the result of one field directly depends on the input of the other field or

vice-versa. These analyses can be of either one-way or two-way analyses. Two way is more complicated compared to the one way as the iteration has to be done for different fields involved in the analysis.

In general, CFA is of two types based on which fields are bring coupled: (a) Load Transfer Method and (b) Direct Method. Load transfer method is used when two or more analyses has to be done in which each analysis belongs to different fields are involved [**2,3**]. So coupling is done between two fields by applying the results of one field in the analysis as loads in the other analysis. Piezoelectric analysis belongs to direct method coupled-field analysis in which only one analysis is done using a coupled-field element type which consists of all necessary degrees of freedom. In

Numerical modelling of PZT-5H soft ceramic model piece using CFA in Finite element software ANSYS shows the voltage obtained from positive piezoelectric effect (sensor function) and displacement from secondary converse piezo electric effect (actuator function) [**4**]. A detailed comparison of damage assessment between different types of PZT patch configuration such as (a) SPC (Single Piezo Configuration), which is conventionally used in EMI technique, (b) DPC (Dual Piezo Configuration, which consists of ring type of patches, (c) MDPC (Modified Dual Piezo Configuration) which uses 4 outer piezo patches as actuators and a centrally placed piezo patch as a sensor shows the improved sensitivity and accurate results in case of MDPC (Adhikari and Bhalla, 2019) **[5]**.

A bonding layer is used to embed a PZT on to the host structure, which plays a crucial role in transferring stresses and strains from PZT patch to host structure and vice-versa. Therefore, the existence of bond layer introduces the shear lag effect, as a result of which the strain induced in the PZT patch is different from that on the surface of the host structure. Shear lag effect is the phenomenon caused due to piezo deformation (actuation/sensing) transferred to the structure via adhesive bond. Practically, it is impossible to introduce uniform bonding layer (constant thickness and required dimensions) into the system and also reduction in dimensions of bonding layer might enhance the output signatures as they provide resistance to the stress transfer.

This paper includes the numerical modelling of sensor-structural system (aluminium beam with bonded PZT patch) using coupled field analysis. Different de-bonding geometries of bonding layer are introduced between the PZT patch and the host structure and obtained the coupled admittance signatures which are compared against the actual conventional epoxy adhesive bond layer system's admittance signatures to analyse the sensitivity of developed model and it's accuracy to warrant the debonding in overall sensor response.

2. Numerical Modelling

The modelling of the system was done using ANSYS software version [6]. SOLID 45 and SOLID 5 were considered as the element types for the structure and the PZT patch respectively. 1/2nd of an Aluminium block/beam of dimensions of 200mm×20mm×6mm with conventional PZT patch of dimensions 10mm×10mm×0.3mm was considered for modelling in order to minimize the computation time with the benefit geometrical symmetry. The material properties of the Aluminium block are listed in table 1 and those of PZT are mentioned in table 2.

Table 1. Properties of Specimen (aluminium block)

Modulus of elasticity (E)	68.95 GPa
Poisson ratio (ν)	0.33
Density (ρ)	2715 kg/m^3
Mass damping factor (α)	0
Stiffness damping factor (β)	3×10^{-9}

Table 2. Properties of Piezoelectric Patch (PZT)

Parameters	Symbols	Values	Unit
Density	ρ	7800	Kg/m^3
Dielectric loss factor	Tanδ	0.02	
Compliance	S_{11}	15.0	

	$S_{22}=S_{23}$	19.0	10^{-12} m^2/N
	$S_{12}=S_{21}$	-4.50	
	$S_{13}=S_{31}$	-5.70	
	$S_{23}=S_{32}$	-5.70	
	$S_{44}=S_{55}$	39.0	
	S_{66}	49.4	
Electric Permittivity	ε_{11}^{T}	1.75	10^{-8}F/m
	ε_{22}^{T}	1.75	
	ε_{33}^{T}	2.12	
Piezoelectric Strain Coefficients	d_{31}	-2.10	10^{-10} m/V
	d_{32}	-2.10	
	d_{33}	5.0	
	d_{24}	5.80	
	d_{15}	5.80	

The de-bonding configuration for the adhesive bonding layer is modelled for each de-bonding case i.e. w.r.t to percentage (%) of bonding layer area is reduced based on the geometry chosen. Figure 2 represents different de-bonding geometries that are used in this research. “Glue” command was used to combine two materials as one entity and to ensure that there exists full connection between PZT and host structure (Aluminium beam). The system is uniformly meshed with 1mm as global meshing size [7]. The sensor-structural system (PZT patch & Aluminium) is applied with boundary conditions such as structural displacements (Degrees of Freedom) on the required areas and the electric boundary conditions on top and bottom surfaces of the PZT patch were applied with a voltage difference of 1 volt i.e. Top surface with 1 volts and bottom surface with 0 volts. Both Top and bottom surfaces of the PZT patch were coupled by ‘VOLT’ DOF. During coupling, one of the node is mastered on the top surface and one of the node is mastered on the bottom surface of the PZT patch. The output data was obtained by acquiring current values from mastered node only.

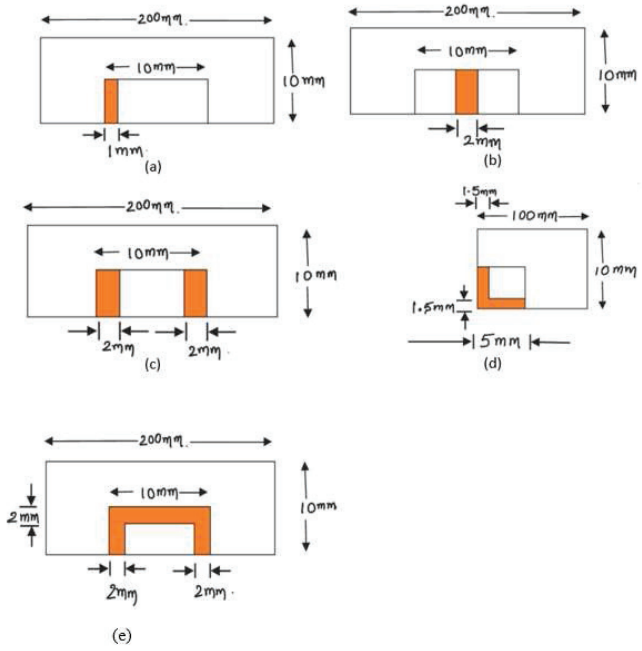

Figure. 2. De-bonding Geometry of adhesive bond layer with (a) 10% reduction in bond area; (b) 20% reduction in bond area; (c) 40% reduction in bond area; (d) 51% reduction in bond area; (e) 64% reduction in bond area.

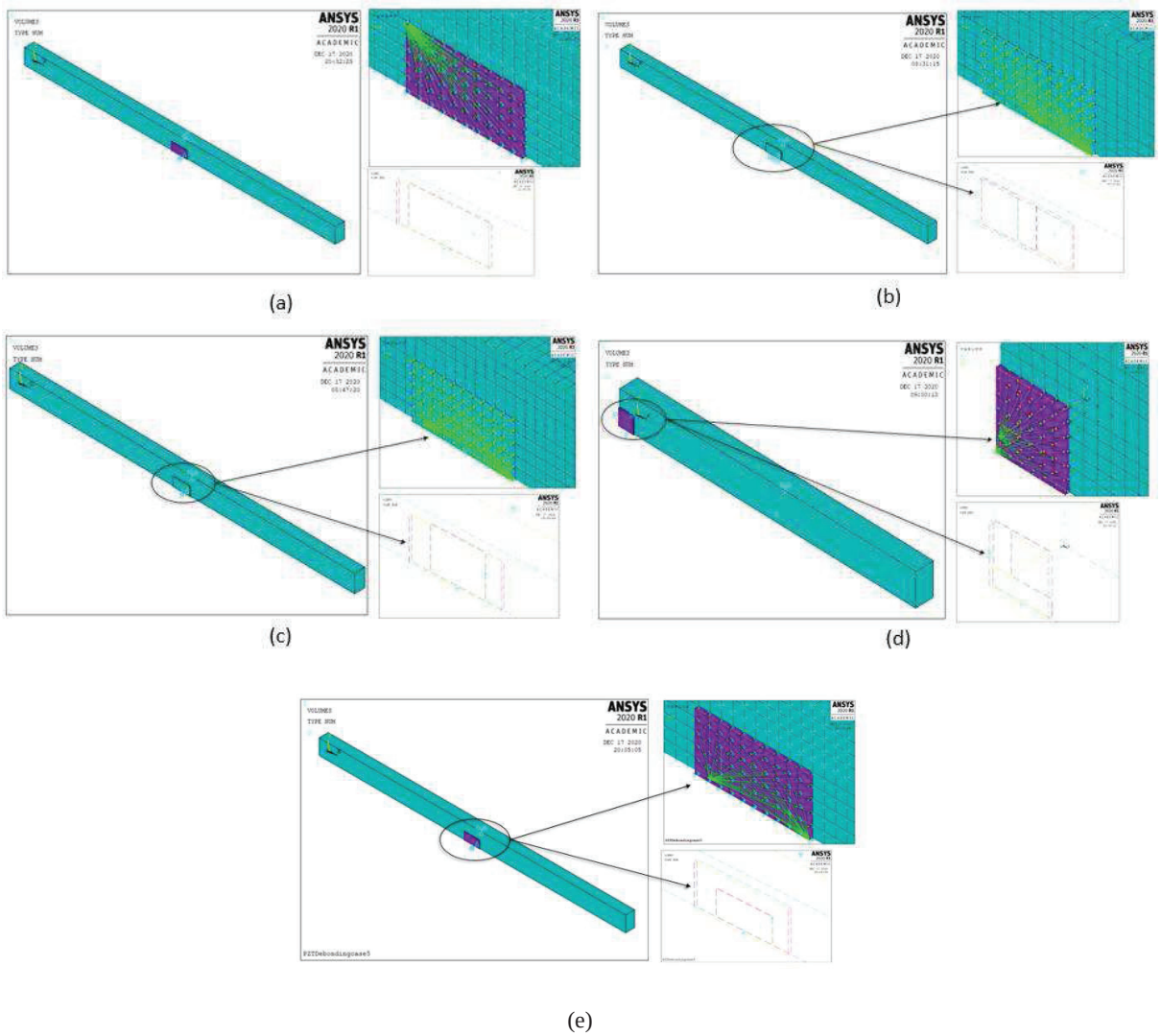

Figure. 3. FE modelling of SPC and Aluminium beam with adhesive bonding layer of (a) 10% de-bonding area; (b) 20% de-bonding area; (c) 40% de-bonding area; (d) 51% de-bonding area; (e) 64% de-bonding area.

Figure 3 represents the numerical modelling of different de-bonding geometries with different bond areas in ANSYS 2020 R1. Dynamic harmonic analysis for frequency range of 0-1000 kHz with an interval of 1 kHz frequency was performed to obtain the charge as output. Stiffness damping factor (β) = 3×10^{-9} is provided to the PZT patch. Current flow labelled as AMPS was measured as reaction forces along top mastered node of the PZT patch from the time history postprocessor of ANSYS. The output data obtained was negative of the charge (-Q) and the value of current flow obtained can be expressed as:

$$I = \frac{d(-Q)}{dt} = -j\omega Q \tag{1}$$

Current flow consists of real and imaginary parts *[-(a+bj)]*. Since the output obtained from time history post processor is negative of current flow, the value of current *'I'* can be written as

$$I = -j\omega(a + bj) \tag{2}$$

$$I = (-aj + b)\omega \tag{3}$$

It can be observed from equation (3) that the real part of current flow will contribute to the imaginary component and the imaginary part of current flow will contribute to the real component of the current. The difference between the current from the top and the bottom node is considered and so the output current *(I_{out})* which consists of real and imaginary components is obtained.

3. Results and Discussion

It is observed that magnitude of highest peak value for conductance signatures of different types of de-bonding geometries is shown in figure 4(a). From figure 4(b), the difference in slope value of all the susceptance signatures varies because the reactive component of signature dominated with adhesive bond properties. Since the active component depends on the properties of both PZT and structure and also the mechanical impedance of the structure couples with the mechanical impedance of the PZT patch only in the active component, the magnitude of the peak and the change in slope of the signatures occurs due to bond properties.

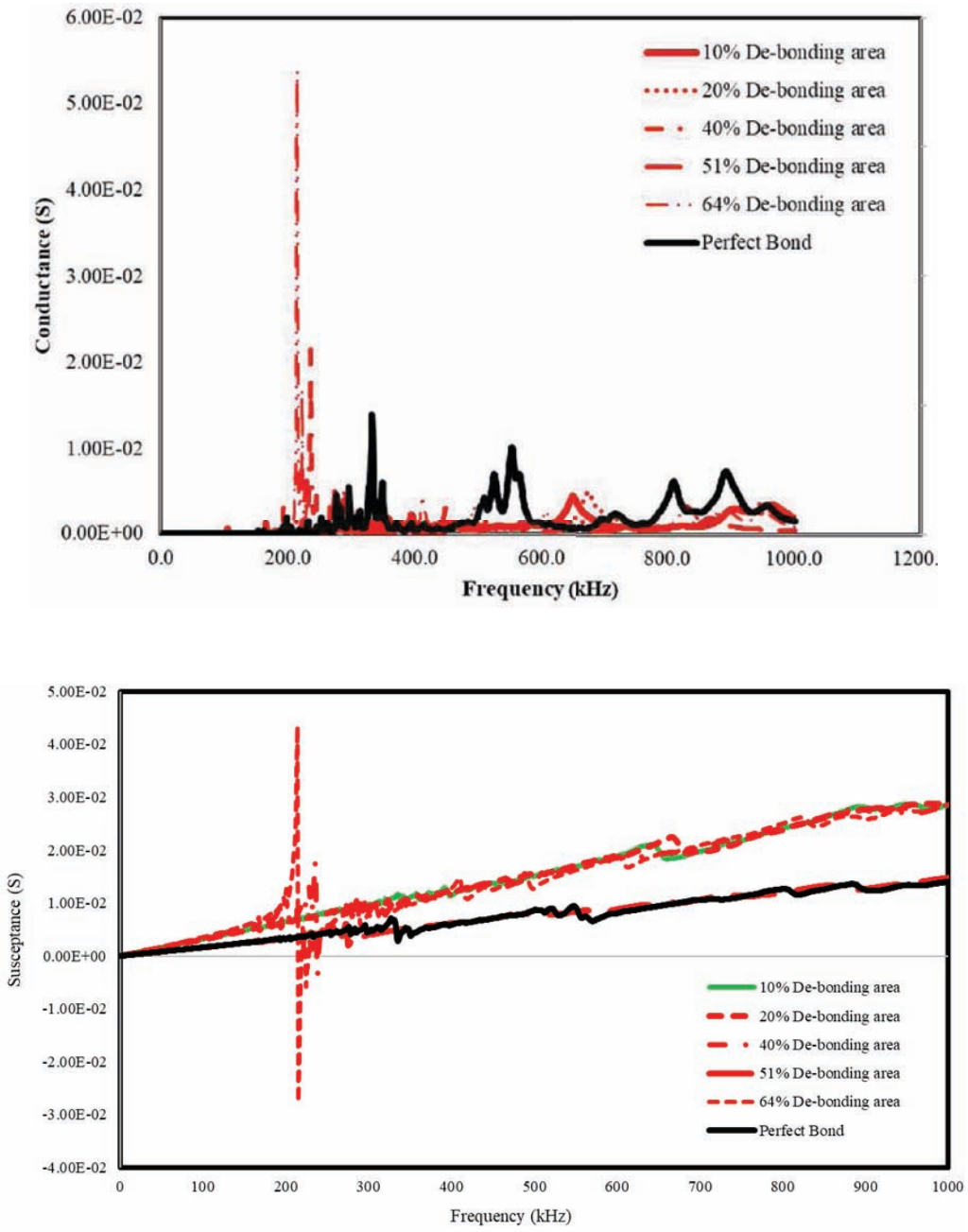

Figure 4. Comparison of admittance signatures for SPC and Aluminium block with adhesive bonding layer of different de-bonding geometries with Perfect bonding condition

(a) Conductance Vs Frequency
(b) Susceptance Vs Frequency

In overall, it can be concluded that with increasing of bond degraded area, the frequency of conductance signature increases but not in steady manner (see Fig 4a). However, the conductance peak value increases significantly,

quite similar to PZT signature in free-free condition. In susceptance, the effect is more evitable with change in slope of the signature curve and peak values (see Fig 4b).

In EMI technique, RMSD index is the most commonly used to detect the quantitative structural damage by computing the degree of deviation of the admittance signatures from the de-bonded PZT-structural system to the base line (complete bond area) signatures. The RMSD index can be expressed mathematically as [8] :

$$RMSD(\%) = \sqrt{\frac{\sum_{j=1}^{N}(G_j^1 - G_j^0)^2}{\sum_{j=1}^{N}(G_j^0)^2}} \times 100 \qquad (4)$$

where G_j^1 is the conductance of de-bonded geometry at j[th] frequency and G_j^0 is the conductance of pristine state at same j[th] frequency.

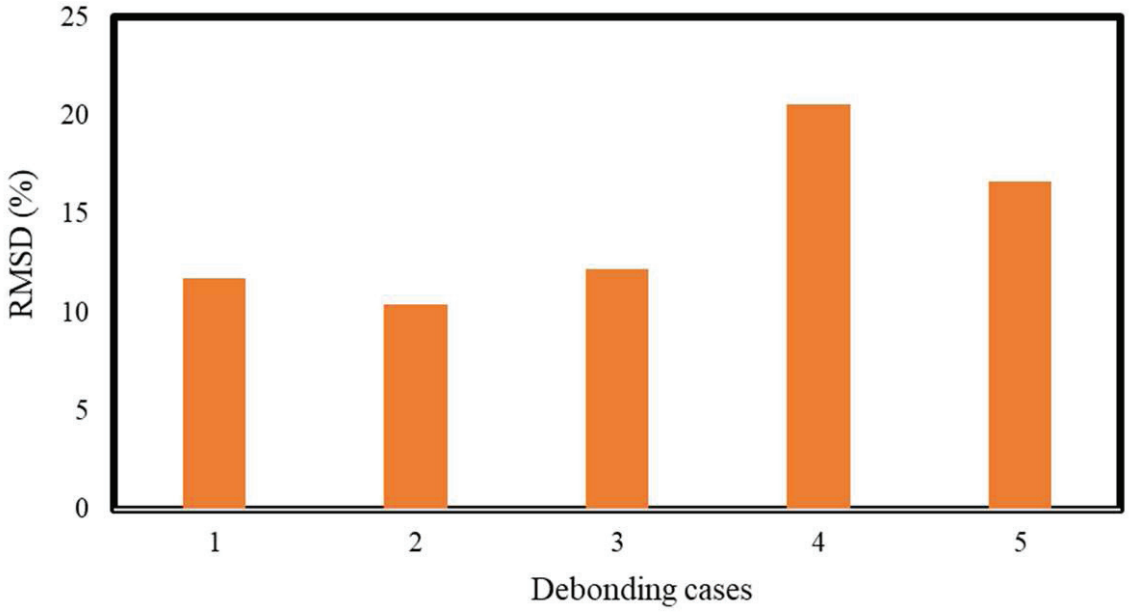

Figure. 5. Variation of RMSD for different case of debonded configuration for sensor-structural system

From figure 5, it is observed that RMSD % varies in significant amount in case of conductance signatures which states that the shift in magnitude of peaks from its pristine state is considerable i.e. the peak values occur at different frequency values and it varies in each case. De-bonding case 4 (51% reduction in bond area) shows the highest RMSD value. It implies the decoupling of sensor-structure is initiated at that stage.

4. Conclusion

It can be concluded from the observations made for all five de-bonding geometry cases that the overall the peak magnitude increases as area of de-bonding decreases and in general, the peaks shift towards right as area of de-bond increases. But for case 5 (64% reduction in area of bonding layer), maximum peak value occurs at around 210 kHz which is similar to that of PZT's for free-free condition (occurs at around 180 kHz) but with reduction in magnitude of the peak. No. of peaks in numerical signatures are less and it might be due to: (i) The damping introduced in the numerical simulation; and (ii) there will be no chemical reactions in bond during Numerical simulation as that in case of experimental setup due to surrounding environmental exposure. The de-bonding effect of adhesive layer on the efficiency of damage detection of PZT when bonded to structure is monitored. The Finite element (FE) coupled analysis is done for aluminium block attached to PZT patch with different de-bonding geometries. Damage sensitivity is analysed and the numerical results are compared with the perfect bonding condition.

5. References

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Monitoring of Settlement in Masonry Arch using FBG Sensors

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Abstract:

Almost all engineering disciplines face the problem of damage detection and assessment. Civil structures built in the past have suffered the consequences of extreme loading events, such as earthquakes, wind, impact etc., over long periods, often leaving them disjointed and degraded. Monitoring of these structures is the need of the hour. It has been observed in the past that the many of important infrastructures failed due to lack of maintenance. Repair measures can only be carried out if these structures are monitored and the condition of the structure is assessed properly.

This paper discusses a vital issue of monitoring of structures undergoing settlements. The test has been conducted on a brick masonry semi-circular arch which is subjected to settlement at one of its abutments. The variation of strains is recorded using Fiber Bragg Grating (FBG) optical sensors at three locations on exterior face of the arch. The strain profile obtained exhibits the necessity of SHM in structures since the sensors are able to monitor the variations which are not noticeable and are obligatory to assess the safety of any structure.

Keywords: SHM, Fiber Bragg Grating, Damage localization, Masonry, Arch, Settlement

1. Introduction

Settlement of the foundation of the structure is a problem that people have faced ever since they first started constructing. Although most of the research activities on vulnerability assessment of buildings focused on seismic actions in the past decades, it is well known that settlements are also prominent causes of damage and even collapse for existing structures [1]. Settlements can originate from natural or human-made hazards such as landslides, floods, subsidence, tunneling etc. The occurrence and type of settlement vary with structures and mainly depends upon the phenomena that trigger its action. Weight of the structure, type of the soil, weakness of a foundation, nearby activities like excavation, drilling, construction are some of the factors behind the mechanism of settlement. The consequences of differential settlements in the Leaning Tower of Pisa are one of the acquainted examples. The clayey and sandy profile of the soil is the responsible factor for its settlement and inclination. There are several other examples where differential settlements has caused significant problems for structures. Hence, researchers are nowadays working towards getting familiar with the potential causes and consequences to have a clear picture to eliminate them or at least reduce their effect to an acceptable level [2][3]. The structural settlement for different building components can be classified into various categories as shown in Fig 1.

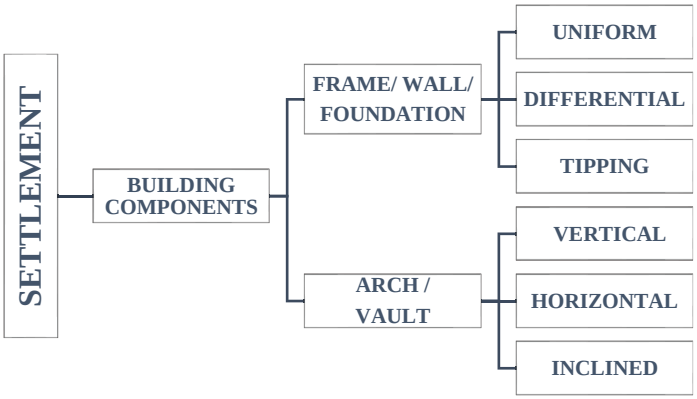


Fig. 1: Types of settlement for different structural elements

Settlement of the foundation is generally vertical displacement of the soil beneath mainly caused by the load of the superstructure. During and after the building construction, minor settlement of the sub-structure is usual and acceptable to a certain degree. However, a potential problem occurs with differential settlements. Differential settlements are uneven foundation settlements that can be the result of numerous causes. The causes of this type of settlement maybe due to uneven load distribution, uneven weight of the structure, excavation on one side of the base, ground movement etc. The types of settlement as mentioned above are shown in Fig 2. Uniform and tipping settlements are mostly without cracks while differential settlement is the major cause of cracks in the structure and has to be investigated well.

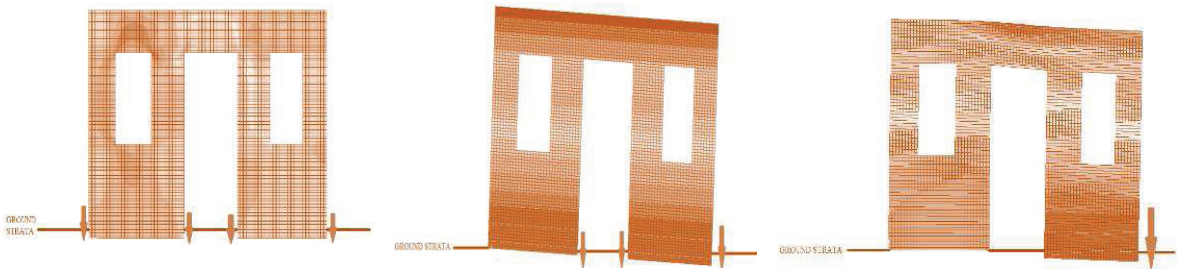


Fig 2: (a) Uniform settlement (b) Tipping settlement and (c) Differential settlement of a wall

In case of curved elements of structure, eg. Arches, settlement mechanisms are different from those occurring in other structure types. Settlement of arch abutments can be classified into three categories: i) Horizontal settlement, ii) Vertical settlement and iii) Inclined settlement [4] as shown in Fig 3. Vertical settlements being most common unlike differential settlement, involves one or both of the abutments tending to displace vertically from its original location. These movements could be along with the abutments or after slippage from the abutments. Therefore, monitoring the behaviour of civil structures under the settlement is very important.

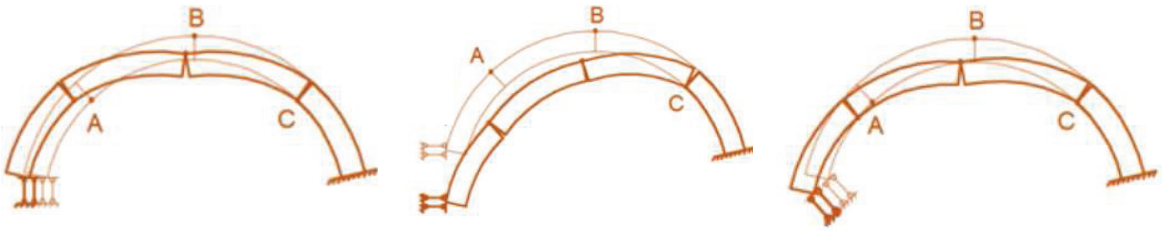


Fig 3: (a) Horizontal settlement (b) Vertical settlement and (c) Inclined settlement of arch structure [4]

Structural health monitoring is playing a dynamic role in the field of civil, structural, mechanical and aerospace engineering where ageing infrastructure is of major concern [5][6]. Numerous researches are undergoing towards the development and deployment of new sensing technologies like bio-inspired sensing [7], vibration-based sensors [8], etc. Owing to the large size and variable environment settings of locations infrastructures of civil engineering structures, they need sensors which are robust, rugged, easy to use and cost-effective [9]. Optical Fibre especially Fiber Bragg grating (FBG) sensors offer a viable such sensing approach with a number of advantages over traditional sensors [10]. Some of the advantages of optical fibres are its immunity to electromagnetic interference, light weight, small size, multiplexing capabilities, ease of installation and durability. Therefore, sensor network made from series of FBG fiber optic sensors may be useful for monitoring of complex civil infrastructures [11] including Heritage structures [12][13].

This paper explores the feasibility of FBG sensors to localize the vurnerable locations in an structure undergoing settlement and predicting their stress behaviour. Experimental study has been carried out on a semicircular brick masonry arch mounted with FBG sensors. One end of this arch has been vertical settled in a controlled manner. In the subsequent sections the instrumental set-up, testing procedure are described and the results illustrated as strain variation for the settlement undergone are discussed.

2. Background

2.1. Structural health monitoring of structures

The monitoring of the structure during a certain period of time can be an adequate measure to help the elaboration of the diagnosis, particularly when there may be non-stabilized phenomena, its evolution. The monitoring of the

building consists in the measurement of parameters, such as, deformations, movements of cracks, levels, temperature variations, etc., in strategic points of the building, at certain moments, during a certain period of time. These are used to predict any disturbances in the desired parameters viz. strain, displacement, temperature variation etc.

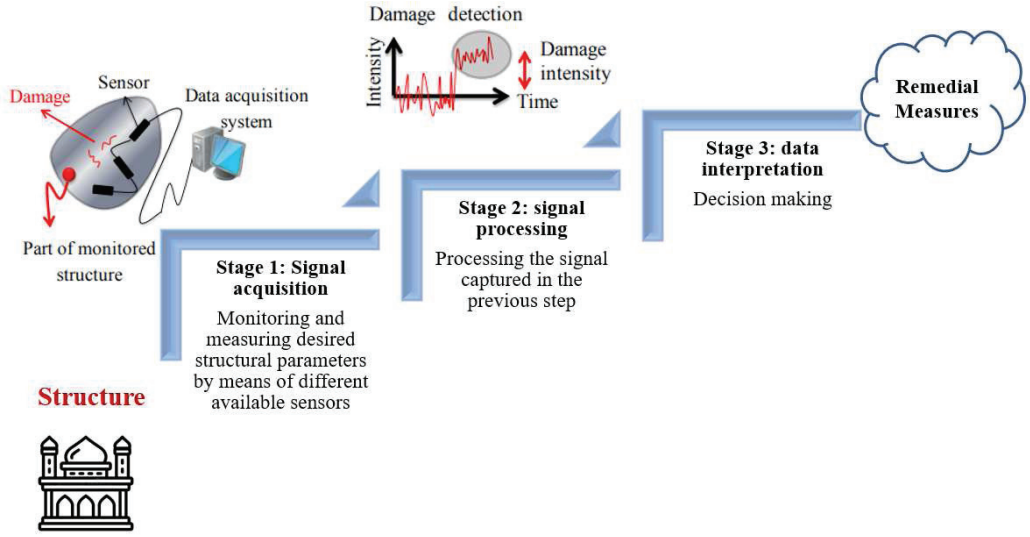


Fig 4. Stages in SHM of a structure

The organisation of a typical SHM system consists of mainly three stages (i) signal acquisition (ii) signal processing and (iii) data interpretation for finally taking decision on remedial measures for a structure (Fig 4) [9].

2.2. Principle of FBG sensors

Fiber optics is very important tool for structure health monitoring. Now a days, these technologies used in many areas such as civil construction work, structure monitoring, medical science, airspace industries, ships, roadways, tunnels etc [14]. Fiber Bragg grating technology is one of the developing techniques for optical fiber sensors which can measure strains, displacements, temperature, vibrations etc. Fiber Bragg Grating (FBG) sensors works as wavelength filter as it reflects back a particular wavelength [15] as shown in Fig 5.

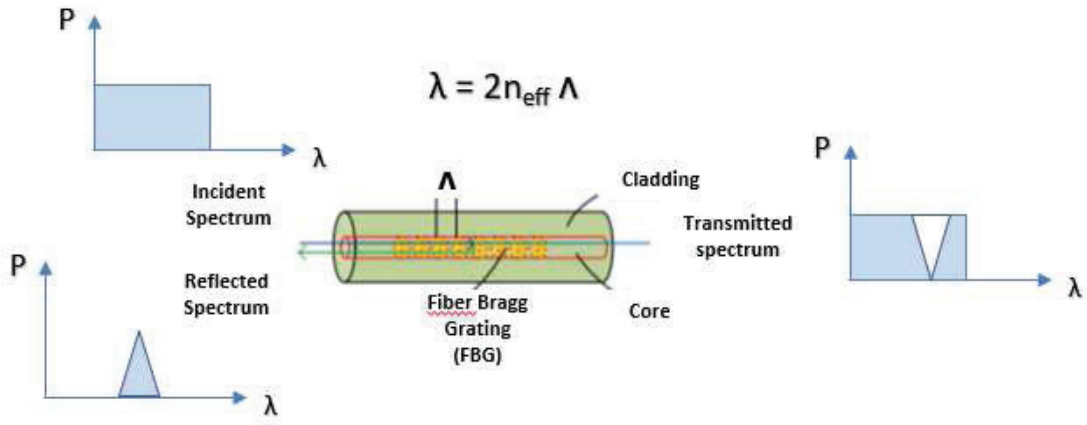


Fig 5. Working principle of FBG sensor

FBGs sensors are similar to conventional sensors such as temperature sensors, pressure sensors, acceleration sensors, humidity sensor etc but having a great advantage against convention sensors is that it is light in weight, easy installation, more accurate, less handling, more reliable, temperature endurance, dielectric nature, immunity to corrosion etc. The main advantage of these type of sensors is multiplexing i.e. multiple number of sensors can be used in a single fiber line.

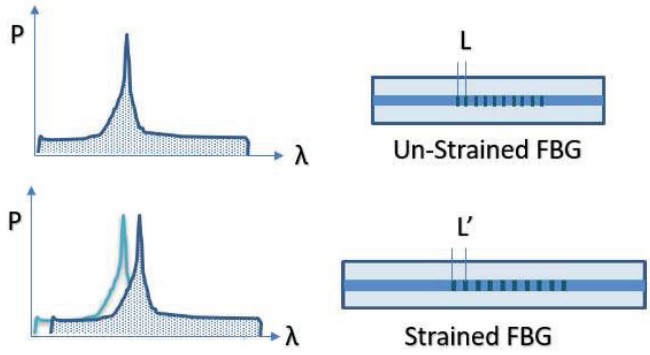


Fig. 6: Wavelength shifting according to strained and unstrained condition of FBG sensor

A fiber bragg grating is basically a spatial variation of the refractive index inside the core of an optical fiber. This variation is created by exposing the core to a periodic pattern of UV light with a defined energy. After this process the grating works as a wavelength selective mirror. At each position of the periodic index variation a small part of the light travelling along the fiber is reflected back. These small portions of reflected light are combined coherently to one large reflection. The wavelength where the maximum reflection occurs is called the Bragg wavelength. The shift in wavelength in strained condition is shown in Fig 6.

3. Experimental Methodology

3.1. Test Specimen

A semicircular brick masonry arch of span 1m have been constructed with 20 wedges. The wedges have been connected using lime-cement mortar to resemble historic structures properties. One end of the arch have been placed on a fixed abutment while another end is kept free for vertical movements. The test have been performed using the settlement testing setup developed at the CSIR-CBRI laboratory which is capable of performing controlled settlement of structures at variable speeds and displacements.

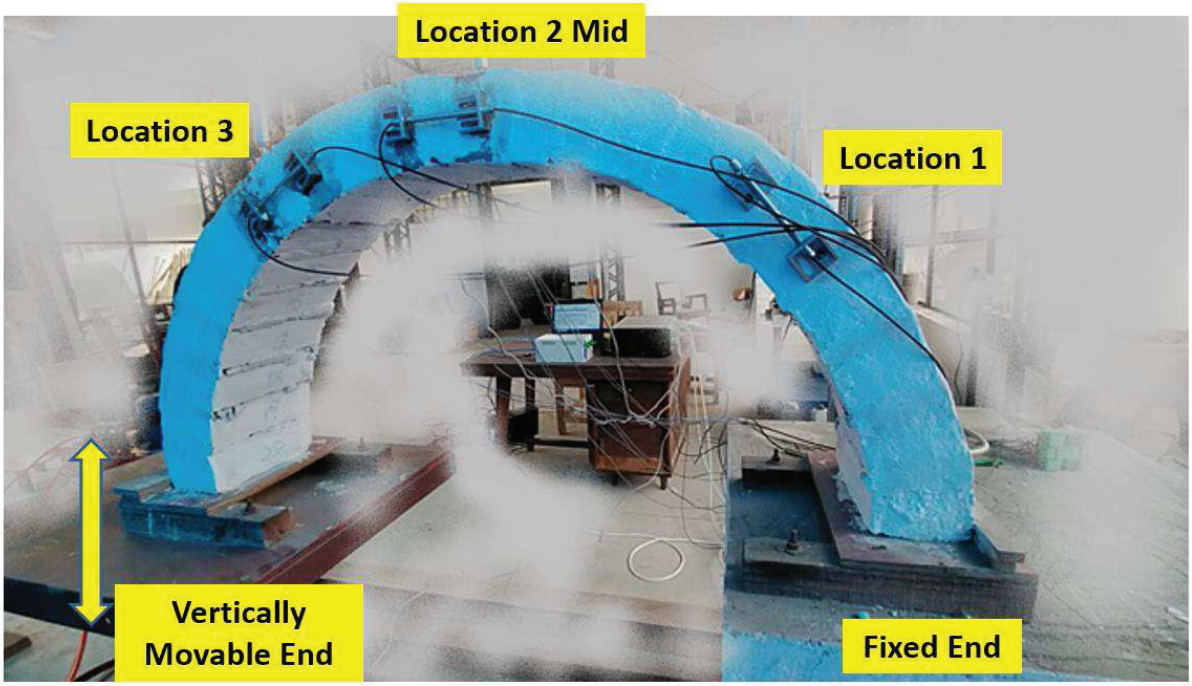


Fig. 7 Brick masonry arch mounted with 3 FBG sensors

The free end of the arch has been settled down to 110mm vertically which is around 1/10th of the span of the arch. To record the strains at different locations, surface-mountable FBG sensors have been used at 3 locations as shown in Fig 7. All 3 FBG sensors are mounted on adjacent bricks with joints in between as shown in Fig 8. This is done

considering that mortar having lower strength with tend to crack first than the units. These gratings are located such that to measure relative strain between the end clamps at a gauge length of 150mm.

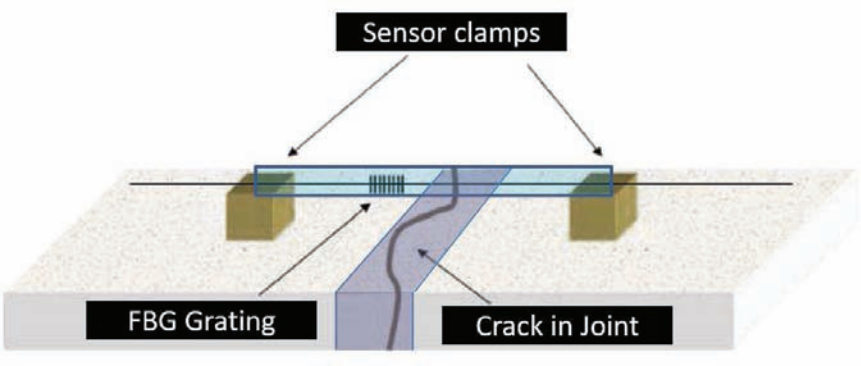


Fig. 8 Mounting of sensor on the adjacent unit keeping the joint in between

A settlement and upliftment mechanical setup have been designed and developed in the laboratory to carry out the tests. This developed setup is capable of simulating the settlement of civil structures in a desired controlled manner. The setup can be used for testing civil structures under the vertical settlement.

4. Results and Discussion

4.1. Hinge formation at the supports

Subsequently, on the settlement of one of the supports of the arch to 110mm, cracks start appearing at certain locations. The ends of the arch displayed the formation of hinges, which is quite realistic for any arch structure.

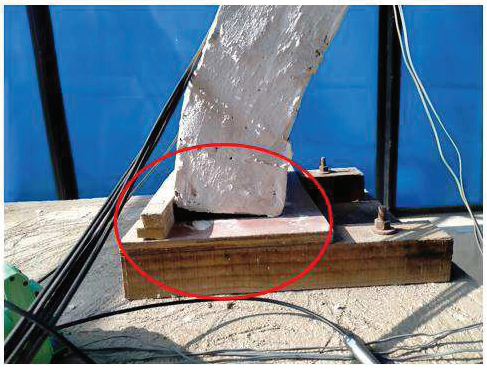


Fig 9 (a) Hinge formation at Fixed End of the Arch

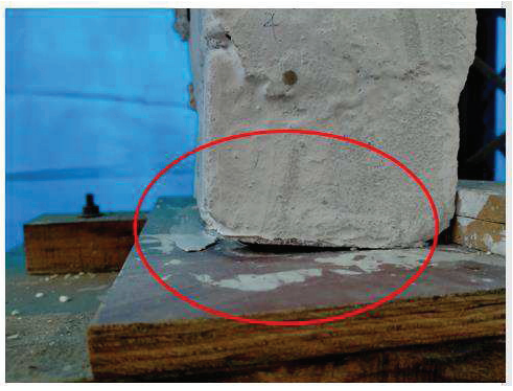


Fig 9 (b) Hinge formation at 110 mm Settled End of the Arch

The hinge formation at Fixed end of the arch have been shown in Fig. 9(a) where hinge is formed on the intrados of the arch while at the settled end, hinge is formed at the extrados Fig. 9(b). The formation of the hinge locations demonstrates the vulnerability of the arch structures during the settlement of abutments. However, other locations of arch are not demonstrating any visible vulnerabilities and so here is the need for monitoring sensors that could determine the susceptible locations for failure. Sometimes, none of hinge formation could be noticed, and on further settlement, these could lead to formation of hinges and could turn the arch into a mechanism.

4.2. Strain profiles recorded using FBG sensors

The strain profiles recorded using the FBG sensors mounted on the three locations of the arch have been discussed below.

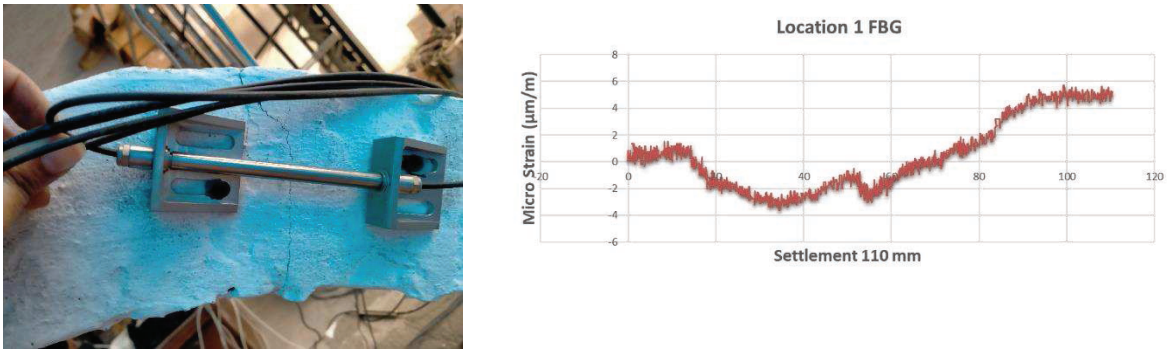


Fig 10. (a) Location 1 after testing (b) Variation of Stain at Location 1 during testing

The condition of location 1 after the settlement is shown in Fig. 10a. The location displays a minute hairline crack. Strain recorded at location 1 is shown in Fig. 10b. The strain variation shows that this location initially undergoes compressive stresses upto 70mm of settlement then develops tensile stresses for further displacements. The maximum value of tensile strain is around 05 micro-strains, which is very low. However, the change in stress profile recorded with increasing displacement is important for understanding the behavior of the arch, which is required for any repair and retrofitting works.

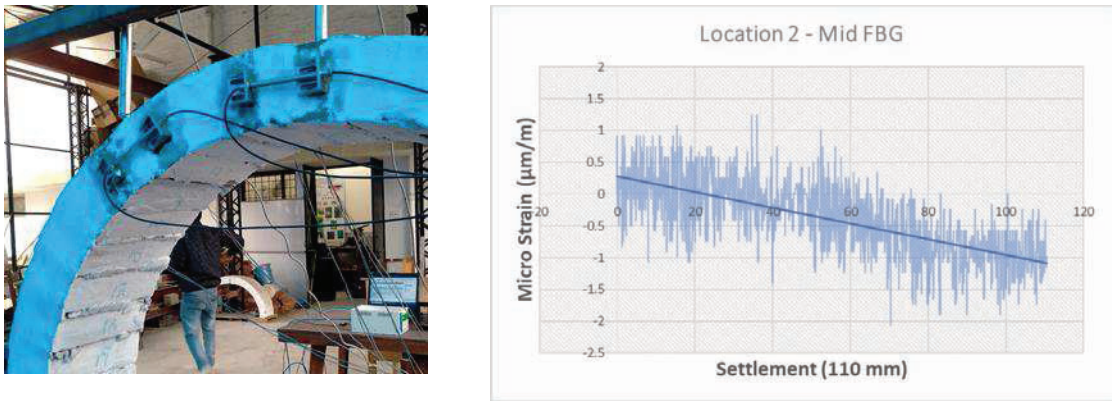
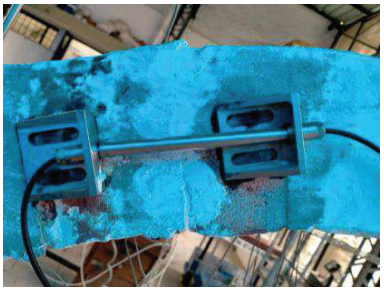
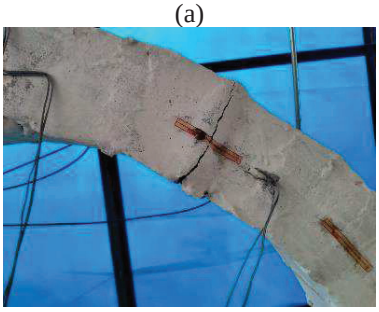


Fig 11. (a) Location 2 after testing (b) Variation of Stain at Location 2 during testing

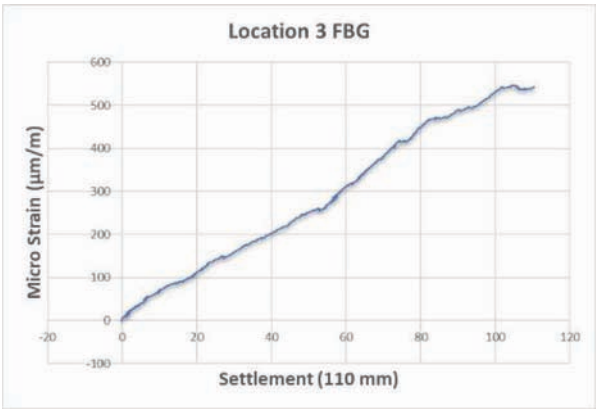
Location 2 i.e. crwon of the arch, doesn't exhibit any type of crack during and after the settlement, as shown in Fig. 11a. Variation in Strain profile with increasing displacement recorded at location 2 is shown in Fig. 11b. The strain values are very low during the entire test, not exceeding even 02 micro-strains in both compression and tension phase. However, the stress profile initially started with compressive towards tension in the later stage.



(a)



(b)



(c)

Fig 12 (a) Location 3 after testing (b) Back side of location 3 (c) Variation of Stain at Location 3 during testing

Joint at Location 3, which is near to the displaced end of the arch, is also not exhibiting visible crack under the FBG sensor (Fig 12a). However, variation in the values of strain are very high nearly 550 micro-strains for the settlement of 110mm (Fig 12c). The stress profile shows tensile stresses for the entire test. This is because the joint is actually developing separation which could be noticed from the back side of the arch as shown in Fig 12b.

5. Conclusion

The process of detecting, localizing, classifying, and providing a prognosis for damage (i.e. change in material and/or geometric properties, boundary conditions and so on) to engineered structures is referred to as Structural Health Monitoring (SHM). FBG sensors monitoring system is suitable instrument for SHM especially because of its only passive optical cable installation and electromagnetic immunity. Although so much advancements have been done in the field of SHM, researchers are still struggling to find suitable monitoring methods for masonry structures specially under various kinds of static and dynamic loads. In the present study, monitoring of a masonry arch undergoing settlement have performed using FBG sensors. Strain developing at different locations have been recorded and analysed. This structural test demonstrates the feasibility of applying optical FBG sensors to study the behavior and performance of civil engineering structures for extreme loading events. The study showed the applicability of optical sensors for static and dynamic monitoring of structures.

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Role of Non-destructive Testing and Evaluation (NDTE) in Water Resource Engineering

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Abstract: The quality of infrastructure and materials used in water resource engineering are vital importance in any civil work designed to last long. Survey of non-destructive testing and evaluation (NDTE) techniques in the field of civil engineering and their applicability to water resource engineering structures like water storage tanks, reservoirs, piping irrigation structures etc. NDTE methods could be employs are discussed. We found NDTE methods are very helpful in ensuring material integrity leading to safe operation and maintenance. We highlight real life advantages, scope and limitations of different NDTE methods from stand point of civil engineering works with reference to water resource engineering structures.

We reviewed the applicability of different NDTE methods based on ultrasound testing (UT), electro-magnetic testing (ET and MT) X - ray (RT) and radar flaw detection technologies, Ultrasonic Localized Guided Wave (ULGW), Ground penetrating radar; Rebound Hammer, Surface Electrical Resistivity test methods etc. & found Half-Cell Corrosion Mapping, Ultrasonic Tasting and Ultrasonic Localized Guided Wave techniques and acoustic emission testing quite interesting.

Among many factors adversely affecting water resource and irrigation structures, extreme variations in climatic conditions and those in water quality parameters, reduce the durability of the structures. We found that effective testing, analysis, monitoring and maintaining of water resource engineered structures can effectively be achieved through development of NDTE techniques. One of the most challenging tasks was to plan, procure and use different kinds of nondestructive testing machines and optimize methodologies by solving real time technical problems and ensure ease of usage.

Keywords: Civil Engineering NDT, Climate, Durability, Ground Penetrating Radar, Half-cell corrosion testing, Non-destructive Testing and Evaluation (NDTE), rebound hammer ULGW technique, Water resource structures.

1 Introduction

Water is one of a vital element of the nature, Water resources engineering (WRE) is the field which includes the study of water , land and recourses, management, equipment, water structures, facilities and techniques etc.. It addresses the best ways to control and ensure its availability for water-related activities – such as irrigation, waste disposal and canal development, ensure safe drinking water for humans, plants and animal usage. WRE is responsible to ensure that the planning and management of

available water supply are adequately leveraged and remain safe to use for as long as possible. They may also be involved in water treatment, so that the quality of water is improved upon for various end users, whether that's recreationally, commercially or industrially.

There are only few renewable sources – such as wind, solar, hydro and biomass. While water may be renewable in terms of the many different ways it can be used and reused, it's not as abundant as it once was, which many earth scientists and climatologists point to as a function of climate change.

The Bureau of Reclamation provides some perspective as to just how limited this resource is in terms of usability, despite its vastness. Surface water makes up about 71% of the planet, which is the equivalent of roughly 326 million cubic miles. At the same time, though, fresh, of this total, 2.5% of it is out of reach, contained in the soil, polar ice caps, the atmosphere and glaciers or too polluted to use safely, so only 0.5% is available for safe usage.

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Water resource engineers may be charged with developing new systems or processes for private or government entities that can preserve freshwater sources and find new ones. This may require the assistance of civil engineers involved as well, design of water purification methods through desalination or creating new equipment for contaminant transport when water is used for irrigation purposes. Understanding what works and what doesn't when it comes to water resource management is often a combined effort and may involve a number of different analyses, including hydrologic, which is the study of the water cycle and directions in which it flows, which may be influenced by weather and other environmental forces. the WRE deals with water resource structures like reservoirs, lakes waterways, breakwaters, sewage conduits etc., takes major role in conservation and management of the water.

In order to use civil engineering structures for full duration of designed safe life, the quality and quantity of materials used, their composition and their ratios, are in general as per SODP (Standard Design Procedure). In the field of Civil Engineering, Water resource engineering structures are critical, so as to conserve the huge amount of water along with its different quality factors, they should be strong enough to take the water load but also entire surface of the structure has to be resistant to climatic variations and composition of material in contact for the designed life.

Especially in water resource engineering, hydraulic action and composition of water can also lead to strength to deterioration the strength of the structure. Hence the hydraulic water resource structure should have the strength to avoid downstream effects and also to counter unexpected negative impacts caused by failure of these structures. Non- Destructive Tasting helps to assess the strength of such structures to give residual life estimation.

Non Destructive testing also helps to avoid the sudden failure of structures by providing the information about in service strength of the material used for construction. Nondestructive testing is carried out by some of the state of the art machines along with established testing techniques.

While Nondestructive testing evaluation gives result by considering key constraint points like, type of material used and its ratios, geometric properties of the structure or structure component and the result also can talk about the age of structure along with existed structure's strength.

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2 Most Commonly used NDE Techniques in Water Resource Engineering

In the field of water resource engineering some of NDE techniques are commonly used because of ease operating procedures, ease of availability of equipment and they offer reasonably accurate results, These NDE techniques like ultrasound testing and evaluation, electro-magnetic testing and evaluation, X - ray and radar flaw detection technologies, Ultrasonic Localized Guided Wave (ULGW), Ground penetrating radar; Rebound Hammer, Ultrasonic Pulse-Echo (UPE), Surface Electrical Resistivity test method, Half-Cell Corrosion Mapping, and acoustic emission testing etc. are found to be most commonly used and found to be special in the WRE.

Brief discussions of each techniques and their applicability are discussed below along with their particular area of usage.

2.1 Ultrasound Testing and Evaluation

Ultrasound testing and evaluation is one of the uncomplicated methods of finding the quality of mortar material. This method involves recording and analysis of ultrasound waves penetrated through the mortar under curing, while hardening process is on, the transmitted ultrasound waves get affected by hydration process. Ultrasound evaluation method gives clear idea about how concrete structures formed by hardening the mortar to get enough strength to structure. In this method factors like, velocity, variation frequency, amplitude etc. are rely on the life span of the material and these can be detected in the course of hardening action (IWB et al. 2000).

It is a quality control method in civil engineering either it may with respect to mortar or concrete. In the field of civil engineering the quality control methods are not dealt in only one factor, the quality control factors in life of the civil engineering are water/cement ratio, humidity, temperature, aggregate to cement ratio etc. are decide the consistency of concrete and the workability. The terms like frequency, velocity amplitude are depends upon age of the material composite. Recording the transmitted or reflected waves to be recorded can be possible only by one term and most probably used term is velocity.

Ultrasound evaluation gives age of the structure component and it will be depend upon different types of materials used for the concrete. In water resource engineering, in case of structures those connect with water directly can possible to give more water content in the concrete compound, so the probability of recording the ultrasound waves in such case gives inaccurate reading. Rather than this, this method is very easy and less error method to find age of compound by analysis of this we can conclude the strength of the concrete.

2.2 Electro-Magnetic Testing and Evaluation

In Electro-magnetic testing and evaluation, the magnetic fields are generated by either permanent magnets or solenoid coils, or yokes. Such magnetic field easily penetrates magnetic materials like Steel. A defect in such material will affect the leakage magnetic fields which can be detected by NDT techniques like magnetic particles. The strength of magnetic field in the material to be tested will increase with increase in solenoid current or when the permanent magnet is close to test object

Similarly an alternating current carrying coil when brought near a conducting material, an eddy current is induced in the test object This induced eddy current is also related to defects in material hence we can detect hidden conductive materials (Paul J. et al. 2006).

This method is very helpful in finding the location of reinforcement or it is helpful in fixing the siltation of reinforcement. In case of large scale construction in water resource engineering structure like bridge and dam construction, the structure contacts directly with water, because of dynamic climate the durability of material reduces in the presence of water results corrosion, finally it decreases the magnetic property of material. As so as magnetic property reduces, finding the quality of reinforcement results cannot be accurate always for structure monitoring cases.

2.3 Radar flow detection technologies

The radar flow detection technology is very important in field of waste water supply or in sewer and in water supply area. In this technique, the water or sewage flow rate is determined by Doppler Effect. Flow determination can be done by using the special kind of sensors and this allow for measurements without contact. It works on the principal that, the sensor is to be fixed outside or at some elevation height of the medium, the signals emitted out from sensor are hits the surface of water. Once reflected signals from the water surface are detected, the change in frequency is created due to velocity in incident and reflected signals the difference in frequencies is termed Doppler shift and this frequency is detected by the sensor to be assess the flow characteristics by the principle of Doppler Effect. (NIVUS, Article ID=15080, 2018).

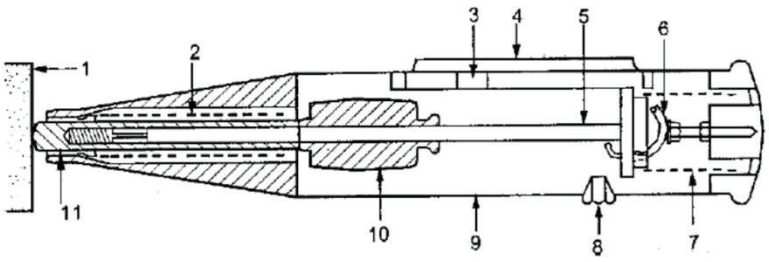
This technology is relies on velocity measurement, it helps to analyze the effect of water quantity as well as quality inside the conduit by knowing the continuous variations in velocity.in case of open channel it is very important to get the velocity variation, because sedimentation problem is a big issue in case of open channel, so as to know sedimentation in the channel, the velocity measurements helps to find solution for this. Sedimentation can cause major impact on inner wall of channel and increasing sedimentation increases discharge capacity of channel.

2.4 Rebound Hammer (Schmidt Hammer)

Principle: The method is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which mass strikes. When the plunger of rebound hammer is pressed against the surface of the concrete, the spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete.

The surface hardness and therefore the rebound are taken to be related to the compressive strength of the concrete. The rebound value is read off along a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer. Depending upon the impact energy, the hammers are classified into four types i.e. N, L, M & P. Type N hammer having impact energy of 2.2 N-m and is suitable for grades of concrete from M-15 to M-45. Type L hammer is suitable for lightweight concrete or small and impact sensitive part of the structure. Type M hammer is generally recommended for heavy structures and mass concrete. Type P is suitable for concrete below M15 grade.

The Rebound Hammer is a simple, handy tool, which can be used to provide a convenient and rapid indication of the compressive strength of concrete. It consists of a spring controlled mass that slides on a plunger within a tubular housing. The schematic diagram showing various parts of a rebound hammer is given in figure below.



1. Concrete surface	5. Hammer guide	9. Housing
2. Impact spring	6. Release catch	10. Hammer mass
3. Rider on guide rod	7. Compressive spring	11. Plunger
4. Window and scale	8. Locking button	

The rebound hammer method could be used for –

(a) Assessing the likely compressive strength of concrete with the help of suitable co-**relations between** rebound index and compressive strength.(b) Assessing the uniformity of concrete (c) Assessing the quality of concrete in relation to standard requirements.(d) Assessing the quality of one element of concrete in relation to another.

This method can differentiate between the questionable and acceptable parts of a structure or for relative comparison between two different structures. This is a hardness test method and is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. The energy absorbed by the concrete is related to its strength. Despite its apparent simplicity, the rebound hammer test involves complex problems of impact and the associated stress-wave propagation. There is no unique relation between hardness and strength of concrete but experimental data relationships can be obtained from a given concrete. However, this relationship is dependent upon factors affecting the concrete surface such as degree of saturation, carbonation, temperature, surface preparation and location, and type of surface finish. The results also affected by type of aggregate, mix proportions, hammer type, and hammer inclination. Areas exhibiting honeycombing, scaling, rough texture, or high porosity must be avoided. Concrete must be approximately of the same age, moisture conditions and same degree of carbonation (note that carbonated surfaces yield higher rebound values). It is clear then that the rebound number reflects only the surface of concrete.

2.5 Ultrasonic Localized Guided Wave (ULGW)

In case of pipe inspection, it is very difficult to find problems inside the pipe, as go as pipe length increases the difficulty of finding problems also increases. ULGW method is pipe inspection method. It is a very good method as compare to other conventional method because old methods are used to test for only limited area and process was also slow. ULGW covers maximum length of area and gives fast result but in old methods test was restricted to small area, to get result for system the whole system has to be tested (SaeedIzadpanah et al. 2008). Almost all pipe, either it may be oil pipe or it may water or sewer pipe are cover with some insulating material in order avoid weathering action causes damage to pipe, insulated pipe testing in order to find the internal damage is very difficult, to find the problem is such cases requires removal of insulators over pipe but it results expensive testing, so as to overcome this problem ULGW method found to be very interested, because in this method waves travels through insulation that is too for long distance helps to find the internal damage or pipe problems without removing the insulating cover over pipe.

This method is mainly used only for oil pipes because as compare to water oil is the expensive liquid, so in order avoid oil loss by leakage, ULGW method is to be carried out. But irrespective of water cost the leakage of water results rapid corrosion and reduces the durability of pipe and pipe network.so to avoid such losses this method should also follow for water lines.

2.6 Half-Cell Corrosion Mapping

Half-cell corrosion method is use for finding the corrosion of reinforcement in concrete elements. Potential difference is called voltage with reference electrode is called half-cell is used to measure the corrosion potential Ecorr, and obtained value of the potential difference between concrete having steel inside, along with standard electrode will depend on the standard electrode used and also depends upon condition of steel inside the concrete (B. Elsener et al. 2003). In inclusion, half-cell potentials of steel metal in concrete cannot be quantify as straight at coherence of concrete/Rebar because of cover of the concrete, thus the potentials are controlled by iR drop in the cover, by using macro-cell current and likely by potentials of junction (B. Elsener et al. 2003).

Corrosion of reinforcement happen mainly due to weather actions, it include climatic variations. Especially in case of water resource structures, the structure durability reduces as age increases because of pollutants of water and its interface with structure may cause chemical action and it reduces the quality of structural material results the average reduction in strength of the structure. Structures contact with water regularly support for corrosion of steel in presence of air from environment. So as to find such defects in structure, finding the corrosion is very important to avoid the failure of structures and structures requires periodical monitoring with respect to corrosion mapping.

2.7 Acoustic emission testing

This technique detects the elastic wave's signals originating from within the specimen which is under some stress. When the material with defects is under stress the defects start growing and creates new surface of defects (expansion of Cracks) releasing energy in elastic waves form These growing defects arise from some physical and thermal deformation of structure yield signals, so that the defect can be detectable only during the growth of defects (Ajay Kapadia et al.).

Acoustic emission Monitoring is the detection of acoustic emission from the test object are the signals emitted by the result of failure and hence AET it is nothing but to listen to the failure.

This technic is mainly used in precast material structure component. The sound may be arising because of crack expansion, the friction and rusting of reinforcement (DaliusMisiunas et al. 2005). For the best maintenance of any large scale sewer lines or water lines, this method needs to be carried out periodically very strictly, so it can give some clues of failure before the cause. We can know when the structure will fail and Acoustic Emission Monitoring is a major NDT tool to inspect concrete and metal bridges.

3. Conclusions

In this paper we have introduced water resource engineering structures as engineering objects which also need Non-destructive Testing and evaluation upon detailed study we find a number of NDTE techniques are being pursued at many a places. As the concrete structures are usually macroscopic and reasonable large objects, Ultrasonic, electromagnetic are more useful and X ray radiography is not feasible, Acoustic emission testing is useful to learn about growing defects, These growing limits when exceed the limits failure occurs This will prevent the disasters from happening. We have also discussed the applicability of Rebound hammer as a hardness testing tool

By studying different types of non-destructive testing and its evaluation says that methods like ultrasound evaluation, electro-magnetic testing and evaluation, X - ray and radar flaw detection technologies, Ultrasonic Localized Guided Wave (ULGW), Ground penetrating radar; Rebound Hammer and Half-Cell Corrosion Mapping, and acoustic emission testing etc. are very much useful in the field of Civil Engineering.

- Among many types of NDE technics, some methods like X - ray and radar flaw detection technologies, Ultrasonic Localized Guided Wave (ULGW), Half-Cell Corrosion Mapping, and acoustic emission testing methods are found to be very interesting and very useful in case of water resource Engineering.
- In case of radar flow detection, it gives the results by contactless measurement of the velocity inside the conduit in the sense of sensors is a very innovative method to analyze the defects by speed of water to the inner pipe surface And this method offers for both open channel and close channel flow. But only by velocity variation we cannot decide the results, in case of sewer lines velocity depends upon many factors like type of pollutants present, number of pollutants present, internal temperature, chemical action among pollutants and with water and overall density of water so cannot ensure the defect's reason exactly.

- Ultrasonic Localized Guided Wave (ULGW) technique is very useful for the pipe inspection in order to find the leakages or defects. It seems to be very costly for inspection of water line networks. Most of the time they use for water pipelines, because water cost is very cheaper than cost of oil. But when you consider leakages in case of water lines it allows the air to interact with more area of pipe with air in presence of water results corrosion of steel content in the pipe and also leakage points in pipe allows foreign particles to enter into the pipe results the clogging of the pipe. Area where joints, pipe fittings are present in pipe cannot give results because of non-uniformity in pipe dimensions or sudden enlargement and sudden contraction of pipe. So these kinds of drawbacks bring some challenges to find economic and accurate method can apply for water lines in order to find internal defects.
- Half-Cell Corrosion mapping technic is useful to find the corrosion in the concrete, this method takes important role because in water resource structures are always in a contact with water, main factor which allow for corrosion is salt water, chemicals and one more is air. Large scale Structures like Reservoirs bund, water runway, bridges, overhead tank requires corrosion finding evaluation without disturbing to structure in sense of reduction of failure risk. But this technique requires technical person should know about corrosion spots and technic of finding.
- Acoustic emission testing takes it role where structures failures give noise waves. It is useful during failures of structural components gives sound waves by recording of waves can recognize as failure. Nondestructive evaluation is better to takes its role before failure of structures or during monitoring of structures. But this method can be taken as final safety technic in case of precast material structures like bridges.

As we have discussed almost all important techniques, each field requires multi nondestructive testing's and evaluation methods for accurate monitoring of structural health, many NDE techniques in single area of interest gives expensive management. Some of cases mandatorily require many tests but priorities of following of different tests in single area of interest are to be challenging by considering operating cost. Assessment of different test follows as period wise is to be scheduling accordingly the types of structures. Overall in field of water related structures requires multi testing facility in a single method, for example finding corrosion, surface hardness and chemical action rate and speed of interaction between water and structural material is required in the field of water resource Engineering in low cost and ease operation.it is very essential to select an appropriate NDE method and technique to get accurate results, it also helps to understand the behavior of the structure at an early stage of the failure. With NDE Methods it will be easy to take precautionary measures, save or increase the life of the structures by making some modifications and alteration if it is necessary. These methods are more cost effective in nature.

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TECHNICAL PAPERS

Characterisation of AE961W Material Using NDT Methods—A Case Study

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ABSTRACT

AE961W martensitic steel material is heavily used for the applications of expendable gas turbine engine development. As a mandatory it is needs to be characterised for its quality for the critical applications. Metrology and NDT methods have been used for its characterisation in the current study. Samples have been prepared with necessary metrological characteristics and are subjected to various heat treatment conditions. The velocity (longitudinal and shear) and magnetism measurements are carried out to assess the effect the heat treatment conditions on the velocity values.

Keywords: Material Chracterisation, ultrasonic, surface roughness, heat treatment

Introduction

Gas turbine materials are expected to perform in varying environmental conditions and are likely to be subjected to failure mechanisms. AE961W is one such material and a steel alloy. It is basically martensitic steel which has properties suitable for the gas turbine applications. GTRE is using this material for the development of a Small Gas Turbine Engine in which this material has an important role for becoming the prime material for shafts, compressor stator and rotor blades, casings etc. The alloy has a good hardenability and due to martensitic structure has high strength, hardness and wear resistance.

Material Characterization consists of evaluation of elastic behaviour, microstructure, mechanical properties etc. NDT methods can be used to characterize properties of gas turbine materials to evaluate rate of degradation and residual life estimation.

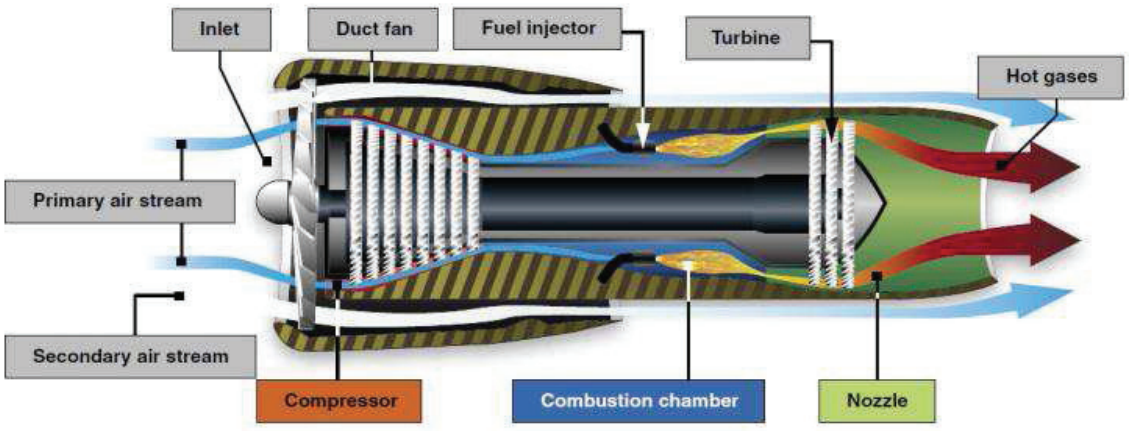

Fig1: Turbofan engine (*courtesy FAA pilot handbook*)

The standard heat treatment for AE961W is 1010^0C/OQ/+560-580^0C/AC or 1010^0C/OQ/+660-680^0C/AC. The ageing treatment of the material usually increases

the hardness and strength. After normal ageing treatment further soaking was carried out increasing the time period. Subsequently, ultrasonic velocity measurements are tried on the samples to see the effect of heat treatment soaking times on the velocity values. The chemical composition of the alloy is given in the table1:

Fig 2: Main properties of AE961W

TABLE 1: Chemical Composition of AE961W

Element		C	Si	Mn	Cr	Ni	S	P	Cu	W	Mo	V	Fe
Wt %	Min	0.1	0.03	0.31	10.93	1.59	0.0007	0.16	0.046	1.73	0.39	0.19	Bal
	Max	0.14	0.43	0.49	11.46	1.85	0.007	0.02	0.082	1.84	0.44	0.27	

The current study is to see the effect of various soaking times on the behavior of the material by measurement of ultrasonic velocities and various other parameters. The experimental studies are carried out with help of specimens of specific size and roughness values.

Characterization using NDT methods

For carrying out the characterization of the AE961W, samples of size 80X30 mm are extracted from the forged bar. The sample designation, size, roughness and geometrical parameters are given in the table2.

Table 2: Sample details

Sample Design.	Diameter (mm)	Thickness (mm)	Surface Finish (Ra in microns)		Flatness		Parallelism (A w.r.t. B)
			A	B	A	B	
AE-1-1	80.124-80.127	30.12-30.14	0.861	0.385	0.013	0.002	0.019
AE-1-2	80.108-80.113	30.12-30.14	0.936	0.146	0.002	0.009	0.012
AE-1-3	80.074-80.081	30.14-30.15	1.582	0.325	0.011	0.008	0.017
AE-2-1	80.138-80.144	30.14-30.16	0.692	0.502	0.013	0.004	0.02
AE-2-2	80.096-80.107	30.17-30.18	0.314	0.88	0.009	0.013	0.023
AE-2-3	80.035-80.045	30.16-30.17	0.803	0.344	0.008	0.003	0.014
AE-3-1	79.880-79.886	30.14-30.16	0.205	0.181	0.009	0.014	0.016
AE-3-2	79.889-79.891	30.13-30.14	0.653	0.733	0.001	0.012	0.043
AE-3-3	80.087-80.079	30.16-30.18	0.506	0.129	0.001	0.006	0.008
AE-4-1	79.830-79.889	30.11-30.13	0.564	0.869	0.006	0.002	0.012
AE-4-2	79.892-79.900	30.14-30.16	0.669	0.856	0.006	0.01	0.01
AE-4-3	80.110-80.119	30.13-3014	0.432	0.429	0.004	0.01	0.01
AE-5-1	80.160-80.161	30.13-30.14	0.833	0.886	0.006	0.008	0.032
AE-5-2	80.136-80.127	30.17-30.19	0.917	0.713	0.02	0.015	0.025
AE-5-3	80.235-80.200	30.19-30.22	0.688	0.742	0.008	0.009	0.017
AE-6-1	80.973-80.976	30.29-30.31	1.007	0.848	0.007	0.008	0.04
AE-6-2	80.978-80.986	30.28-30.29	0.75	0.87	0.016	0.006	0.012
AE-6-3	80.914-80.917	30.30-30.31	0.591	0.701	0.001	0.004	0.007
AE-7-1	80.962-80.963	30.29-30.30	0.526	0.835	0.01	0.011	0.021
AE-7-2	80.986-81.018	30.26-30.27	0.415	0.689	0.003	0.007	0.052
AE-7-3	80.915-80.918	30.29-30.30	0.565	0.997	0.004	0.007	0.01
AE-8-1	81.001-81.005	30.26-30.29	0.895	0.769	0.005	0.015	0.034
AE-8-2	80.997-81.003	30.27-30.30	0.902	0.829	0.003	0.014	0.032
AE-8-3	80.963-80.969	30.28-30.29	0.62	0.54	0.019	0.011	0.016

A total of twenty four specimens are manufactured from AE961W material. Dimensional and geometric feature measurements and surface roughness measurements are carried out. Heat treatment of the specimens is carried out as per the decided cycle for the material specimens. The pictures of the samples are shown in the figure1. The heat treatment followed is given as:

a) Preheating 300-400^{0}C for 15-30min in Air circulation furnace
b) Hardening 1010±50^{0}C for 15min/hr in vacuum furnace followed by GFQ

For other set of samples the heat treatment temperature is 1010±50^{0}C with varying soaking periods from 4 to 14 hours.

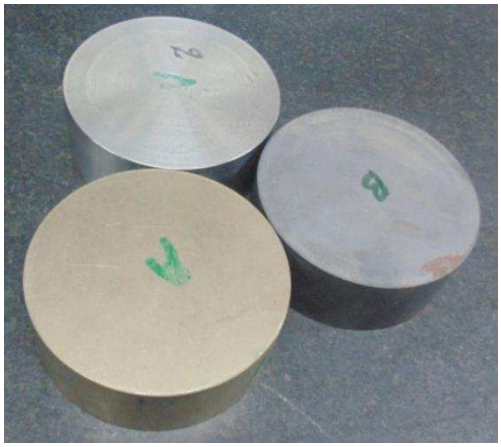

Fig.3: AE961W specimens

The methodology employed for the evaluation/characterisation of the AE961 W samples is explained in the table3. Ultrasonic testing for the velocity, attenuation measurement and the Rockwell testing for hardness measurement was carried out on all the samples.

Table 3: Characterisation methodology and parameters

Material	Heat Treatment Condition	Methodology	Parameters
AE961W	ST, STA, STA+4hrs, STA+6hrs, STA+8hrs, STA+10hrs, STA+12hrs, STA+14hrs	Ultrasonic Testing, Rockwell hardness testing	Longitudinal velocity, Attenuation, Rockwell hardness

Ultrasonic velocity measurement was carried out on USN-60 model and hardness measurement was carried out on Ultrasonic equipment. The details of the equipments used for the measurements are given in the table 4 and 5.

Fig4: Ultrasonic velocity measurement on specimen with USN60 equipment

Table 4: Ultrasonic shear velocity, hardness and attenuation in AE961W samples in heat treated condition with variable soaking periods

Sample Design.	Heat treatment	Shear Velocity, m/s	Hardness, HRB (Mean)	dB= 20logH2/H1	dB/mm
AE-1-1	1010±5^{0}C for 15min/ hr in vacuum furnace followed by GFQ (ST)	3268	55.70	10.64	0.177
AE-1-2		3235	64.30	10.64	0.177
AE-1-3		3288	59.84	11.09	0.184
AE-2-1	STA	3209	74.40	11.41	0.190
AE-2-2		3176	70.30	10.64	0.177
AE-2-3		3189	69.75	10.94	0.182
AE-3-1	STA/4hours	3201	72.75	11.09	0.184
AE-3-2		3204	64.20	11.41	0.190
AE-3-3		3174	79.25	10.94	0.182
AE-4-1	STA/6hours	3200	77.10	10.94	0.182
AE-4-2		3194	75.20	11.09	0.184
AE-4-3		3229	76.30	10.64	0.177
AE-5-1	STA/8hours	3210	67.15	12.04	0.200
AE-5-2		3233	68.05	11.09	0.184
AE-5-3		3193	64.05	11.09	0.184
AE-6-1	STA/10hours	3209	68.50	10.34	0.172
AE-6-2		3197	79.45	10.64	0.177
AE-6-3		3201	74.05	11.25	0.187
AE-7-1	STA/12hours	3173	74.95	11.25	0.187
AE-7-2		3198	67.00	11.09	0.184
AE-7-3		3218	70.75	11.09	0.184
AE-8-1	STA/14hours	3193	70.30	11.49	0.191
AE-8-2		3192	71.10	11.41	0.190
AE-8-3		3216	58.65	09.69	0.161

RESULTS, DISCUSSION & WAY FORWARD

The results of the study revealed the an appreciable change in the shear velocity, hardness and attenuation values with respect to the various heat treatments carried out on the test specimens of AE961W material. The relation generated for the specimens w.r.t. respective hardness value is given in the Fig.5.

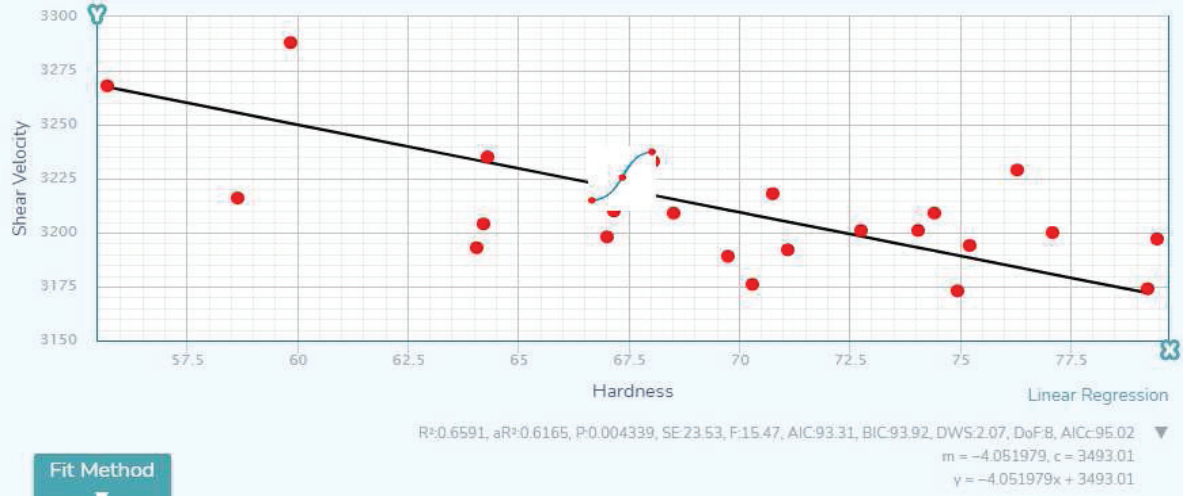

Fig5: Ultrasonic Shear Velocity vs Hardness for AE961W

The fitting method is a linear regression with a regression coefficient of 0.66 giving a positive relation between hardness and shear velocity at various heat treating stages.

The methodology can be adopted for the relation for the practical engines components like shafts, casings etc. going through various heating conditions during the testing at test levels.

Future work will be evaluated as residual magnetism measurements w.r.t. changes due to heat treatment and also correlating the ultrasonic material properties with the actually affected parts

Acknowledgements

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REPORT OF ANNUAL CONFERENCE AND EXHIBITION ON NDE (NDE 2021)

The annual flagship event of ISNT "Conference and Exhibition on NDE (NDE 2021)," was conducted on a virtual platform during 9th - 11th Dec 2021. The inaugural function of this 2nd Virtual Conference of ISNT was held on 9th Dec 2021. Dr Tessy Thomas, Director General (Aeronautical Systems), DRDO was the chief guest; Mr John Iman, President of American Society for Nondestructive Testing (ASNT) and Dr IkKeun Park, President of Korean Society for Non-destructive Testing were the Guests of Honour for the hybrid inaugural function of the conference. In her inaugural address, Dr Tessy Thomas highlighted the importance of the NDE in the Aerospace sector and congratulated ISNT for the efforts taken to create and spread awareness of NDE in the industry. Mr John Iman and Dr IkKeun Park stressed the need for enhanced collaborative efforts between the NDT societies worldwide. Dr B Venkatraman, Distinguished Scientist and Director of Indira Gandhi Center for Atomic Research (IGCAR), was the Chairman of the Conference and Shri Bikash Ghose, Group Director, HEMRL, DRDO, was the convener of the conference.

More than 600 participants attended the conference represented by various Service and Manufacturing Industries, Academia, NDE Entrepreneurs, R&D Institutions from Space, Defence, Atomic Energy, Power, Railway etc. In this edition, special focus was given to the women contributors in NDE. Many woman achievers shared their knowledge and experience. This virtual conference and exhibition, ''NDE 2021'', had three Pre-Conference tutorials held on 3rd & 4th Dec 2021, two Memorial talks, four Plenary talks, more than 30 invited talks, and three special sessions, and three special sessions entertaining games. More than 165 papers were presented in 35 sessions spread over three days by the researches working in the different areas of NDE. Mr V Manoharan & Dr Ravibabu Mulaveesala have spearheaded the technical committee of the NDE conference, and Dr DeepeshVimalan spearheaded the Pre-Conference Tutorial. Dr Baldev Raj memorial talk was delivered by Prof Xavier Maldague, University Laval, Canadaand Dr S K Jha, CMD of MIDHANI delivered the Mr Ramesh bhai Parikh memorial talk.

About 25 national and international exhibitors showcased their products and services through the state-of-the-art 3D virtual exhibition. The exhibitors had the opportunity to showcase their products, technologies and services right away from home or office through a wide range of interactive online tools. M/s Olympus was the Principal Sponsor of the Conference.

NDE 2021, another landmark event from ISNT in the annual series, was conducted with a different flavour and charm that ensured fulfilling experiences of all delegates, speakers, invitees, and exhibitors on all fronts - technical, professional and social with the comfort of being at home or office.


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TELEDYNE FLIR
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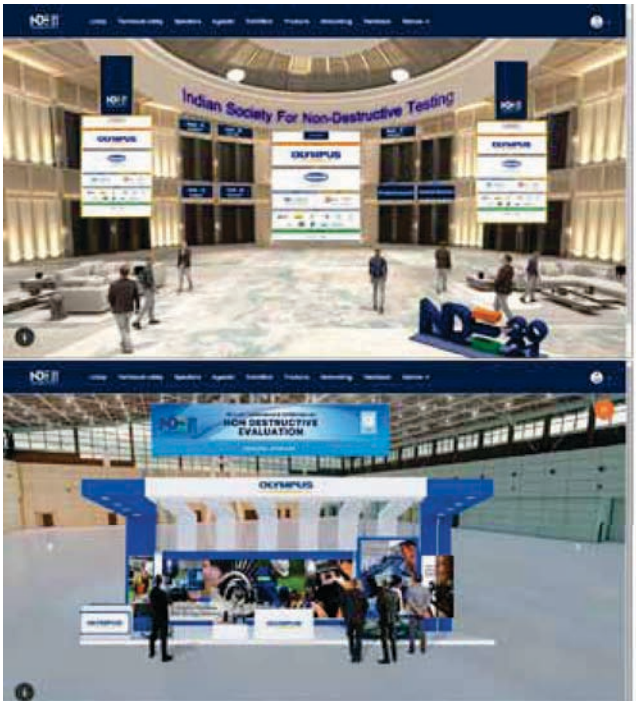
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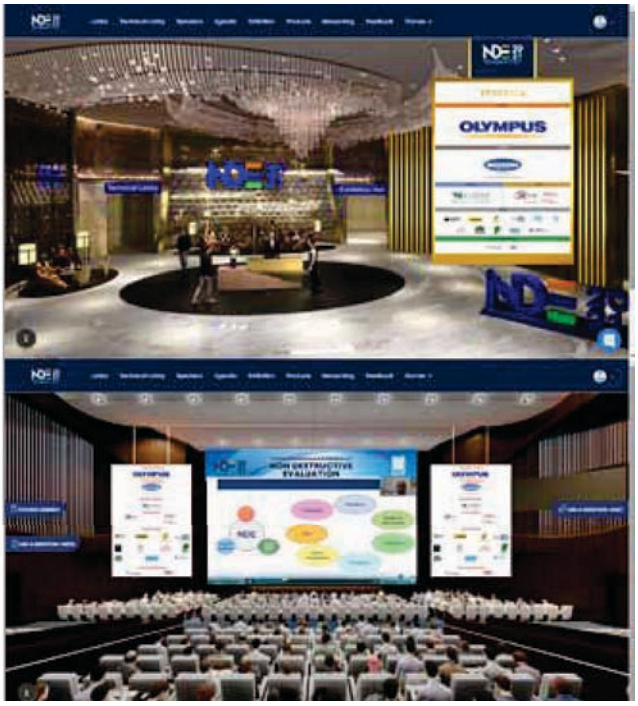
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"It is good to have Education, it is better to have Experience, but it is essential to have Training!"

ISNT - Training Management Board (TMB)

Over the last three decades, the training and certification activities of ISNT have been coordinated mainly by the National Certification Board (NCB) of ISNT, especially for the IS 13805 scheme, where BIS had authorized ISNT to be the sole body for this purpose. With NCB-ISNT getting formal accreditation by NABCB in accordance with ISO 17024 for initiating a new scheme based on ISO 9712 and having an international reach in the name of International Certification in NDT (ICN), it also became imperative that the training and the certification activities have to be operated independently to avoid conflict-of-interest and confidentiality issues. In view of this, ISNT has decided to form a Training Management Board (TMB) with the below-given objectives and scope,whose sole responsibility would be to manage all the training related activities and policies for the certification schemes of ISNT. The National Governing Council (NGC) of ISNT has formally approved the formation of TMB in the meeting held on 29th January 2022, and it was put in place immediately thereafter with a set of 15 members and 7 Ex-Officio members.

Objectives of TMB

Training

- Standardize and Harmonize the Content, Quality and Delivery of Training courses (leading to certification) being conducted by any authorized entity under the ISNT banner
- Key focus on Level 1, 2 and 3 certification courses being conducted by ISNT Chapters and other Institutes
- Act as a nodal agency for addressing all NDT/Inspection related special Training needs of the Indian industry

Authorization of Training Centre's

- Streamline and create a Robust process to establish Authorized Training Centres (ATC) for IS13805 and ICN across the country (and abroad if needed) to help spread ISNT's schemes more widely

Scope

- Training activities related to IS13805 certification
- Training activities related to ICN certification
- Any Special Training programs of interest and relevance to be organized by ISNT based on current trends OR on request from Industry to help spread NDE Science and Technology across the country
- Developing, implementing and executing the method and process of Authorizing Training Centre's for both IS 13805 and ICN
- Establishing a self-sustaining model for revenue generation for continued operations and growth of TMB

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Mr. S. Harikrishna
Hon. Secretary

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Meeting Schedules

The proposed dates for Meetings for the year 2022

Date	Meeting	From	Time
18th June 2022 (Saturday)	TMB	11:00 hrs	13:00 hrs
	NCB	14:30 hrs	16:30 hrs
	Steering Committee	16:45 hrs	17:45 hrs
19th June 2022 (Sunday)	NGC	09:30 hrs	14:00 hrs

Date	Meeting	From	Time
10th September 2022 (Saturday)	Chapter Chairmen's Meeting	10:00 hrs	12:00 hrs
	TMB	12:00 hrs	14:00 hrs
	NCB	15:30 hrs	17:30 hrs
	Steering Committee	17:45 hrs	18:45 hrs
11thSeptember 2022 (Sunday)	NGC	09:30 hrs	14:00 hrs

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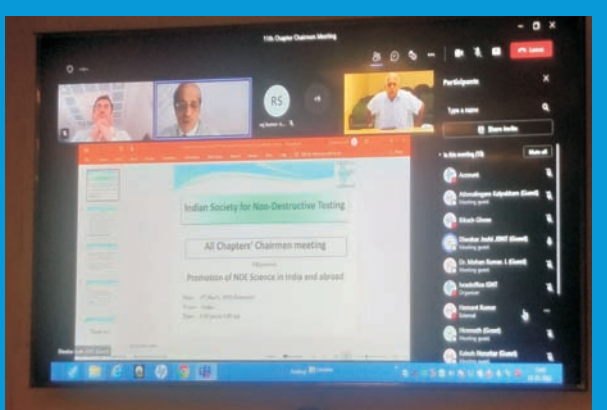
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