

**TECHNICAL BULLETIN OF INDIAN SOCIETY FOR NON-DESTRUCTIVE TESTING (ISNT)
THIRUVANANTHAPURAM CHAPTER**

Vol.28 No.2

www.isnttvm.org

July - December 2013

From Chairman's Desk

Dear Members,

Let me thank the past executive committee for the impressive record of activities during their tenure, including bagging of the best chapter award 2012 for Thiruvananthapuram chapter. I assure the members that the new Executive committee will derive strength from the strong foundation laid, for furthering the activities of the chapter.

We have already conducted a lecture programme on 5th September in collaboration with Inspection technologies and RVI, on Advancements in Digital Computed Radiography, 3D Computed Tomography, Remote Visual Inspection and Inspection of Composites using Phased Array. The young engineer's forum of the chapter has already chalked out a plan to keep the members aware of the current topics of interest through a lecture series. Action is already afoot to have an awareness programme on NDT in academic institutions, which is a regular unique activity undertaken by our chapter. We will pursue training the NDE practitioners to assure that the best is always delivered by them, when the basic techniques are applied. Members from our chapter have attended and participated in the 14th Asia Pacific conference held in Mumbai during November 2013. Details are given in the following pages.

I request the members of the chapter to continue to support the chapter by actively participating in the programmes organised.

With best wishes,

Saratchandran S
Chairman, TVPM Chapter

BINU P. THOMAS received NATIONAL NDT AWARD 2012



Indian Society for



Non Destructive Testing

IMAGE

Technical Bulletin of Indian Society for Non-destructive
testing Thiruvananthapuram chapter

Volume 28 No. 2

July-December 2013

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Editorial...

Dear Members,

This issue of IMAGE comes to you with Christmas and New Year around the corner. I wish all members, "A Merry Christmas" & "A Happy New Year".

ISNT, Thiruvananthapuram chapter has always been vibrant from its inception. It has received the 'Best Chapter' Award twice. That speaks volumes on the activities of the chapter and its standing at the National level.

A new Executive committee has taken over the responsibility under the able chairmanship of Shri S. Saratchandran. As a chapter member, I wish the new office bearers all the best for the next two years.

At the same time I thank Shri S. Saratchandran and other EC members for nominating me as editor for IMAGE and Shri Ajay Kumar as member, Editorial Board. We will give our best to continue the present image of IMAGE and improve on it as well.

Sridhar S.

CONGRATULATIONS

THOMAS PANACKAPARAMBIL BINU won National NDT Award 2012 in recognition of his significant contribution to NDT Systems innovation and Development. His innovations were in the development of a Portable real time digital holographic system^A (Patent No. 247506) to use not only in the laboratory but also for on-line & in-situ NDT testing at work centers. He has also developed an HDigital© software, which eliminates the requirement of laser for reconstruction of holograms. VSSC licensed HDigital© software to a third party and is being marketed by them since July 2011.

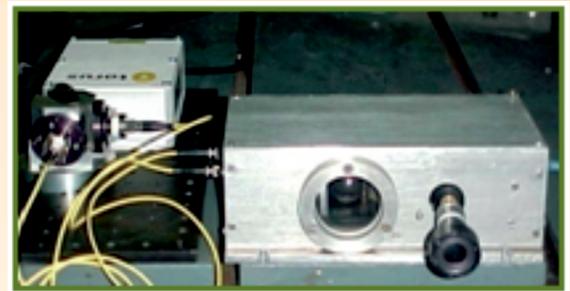


Binu P Thomas

Specific Contribution by Binu P Thomas

a. Portable real time digital holographic system^A (Patent No. 247506)

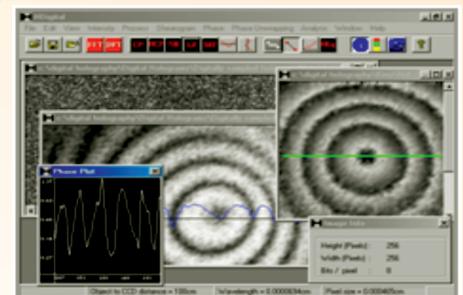
- ❖ Indian patent (Patent No 247506) was granted to this system in April 2011.
- ❖ It is a portable and modular system of in-line configuration consists of a recording head connected to laser through optical fibers. It maps surface deformation and strain simultaneously in real time of any structure under minute loading.
- ❖ It is an all-optical-fiber-system and can be easily coupled to any laser.
- ❖ Suitable for on-line & in-situ NDT applications.
- ❖ Holograms are recorded and interferograms are generated within a few milliseconds where as it takes about an hour with conventional method.



Digital holography system

b. HDigital© software

- ❖ Copyrighted this software. Diary No 324/2004COSW.
- ❖ Advanced image processing software for numerical reconstruction and processing of digitally sampled hologram.
- ❖ HDigital eliminates the requirement of laser for reconstruction of holograms.
- ❖ Multi window stand-alone package developed in Visual Basic under WINDOWS platform.
- ❖ Software helps in non-destructive testing of structures through generation of double exposure holographic interferograms and holographic shearograms from two single exposure holograms. Other main features include generation of intensity, phase and wrapped phase maps, phase plot, phase unwrapping and basic image processing features.



Hdigital© environment

c. HDigitalRT

- ❖ Real time version of HDigital©.
- ❖ Used for on-line recording and reconstruction.
- ❖ Simultaneous generation of interferograms and shearograms.
- ❖ Save results in video / bitmap format for easy and fast retrieval.
- ❖ LabVIEW codes in WINDOWS platform.
- ❖ Numerical shearing helps to control strain sensitivity unlike commercial shearography system where shear amount is fixed with a n optical element.



HDigitalRT environment

d. On-site digital holographic NDT system (2011)

- ❖ A portable off-axis holography system was configured for on-site testing of sandwich structures.
- ❖ System mainly consists of 6W continuous wave Nd-YAG laser, high resolution CCD camera, high power optical fiber and HDigitalRT software.



On-site off-axis digital holography system

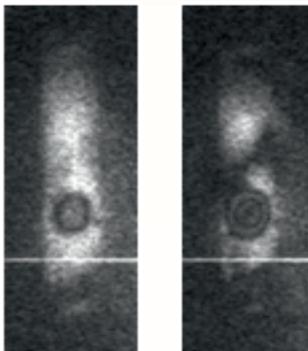
e. Time average digital holography (2011-2012)

- ❖ Implemented time average digital holography.
- ❖ Can visualize the mode shape or vibration amplitude of any structure under vibration.

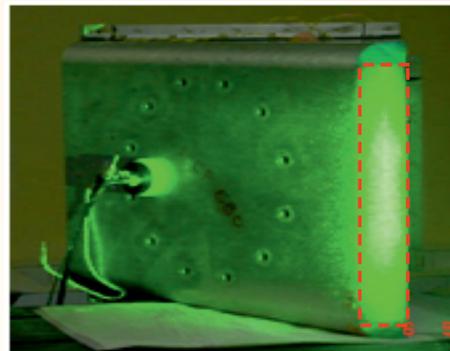


Plate under vibration: Time average holograms vs numerical plot

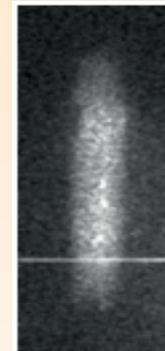
- ❖ Best NDT candidate for the in-situ debond detection in sandwich structures. Debonds locally resonate under vibration and can be easily visualized.
- ❖ Used successfully for NDT of honeycomb sandwich satellite adaptors with sharply curved edges where conventional techniques failed.



Defective edge



Satellite adaptor



Non-defective

f. Digital hologram shearing system (2011-2012)

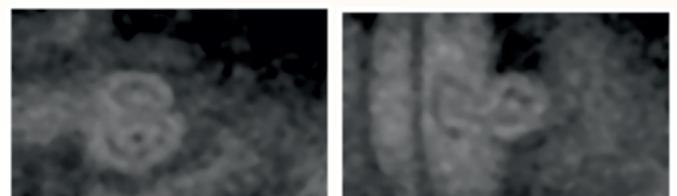
- ❖ Developed whole field strain mapping system based on digital holography.
- ❖ Successfully used for NDT of Titanium alloy liners where conventional techniques missed or failed to detect the defects.
- ❖ Whole field and fast nature made this as an inevitable NDT tool for first hand screening.



Ti alloy liner



Interferogram showing defect



Shearograms showing defect

“14th Asia Pacific Conference on Non-Destructive Testing” was organised during November 18-22, 2013” at Mumbai, India

- ❖ Dr S Annamalai Pillai, former chairman, ISNT, Thiruvananthapuram chapter; gave an invited talk in “NDE in Aerospace” Session, which was chaired by Prof. Jan Achenbach, Walter P. Murphy, Distinguished McCormick School Professor Emeritus of Civil, USA. Title-“Optical NDT methods with application to Launch Vehicle components”. Dr Annamalai also chaired a session titled “Industry Specific-Aviation”. He was also an organizing committee member for the conference.
- ❖ Shri Adal Arasu presented a paper titled “Characteristics observation in Flaw Detection using Guided waves”.
- ❖ Shri Jeby Philip Presented “Structural Integrity assessment of aluminium liquid propellant tanks during proof pressure testing using acoustic emission”.
- ❖ Shri Cherian Thomas and Shri K.K. Roykuttan were the other members of Trivandrum chapter, who attended the conference.
- ❖ Dr Annamalai Pillai and Shri Adal Arasu, Former Vice Chairman, ISNT, Thiruvananthapuram chapter; participated in the NGC meeting on 17th Nov, 2013.

Technical talk organised by Young Engineers Forum

A technical talk was arranged by the Young Engineers Forum on 08/11/2013 at Hotel Nandanam Park. Shri Ajay Kumar from CNDT Division, CMSE, VSSC has presented a topic titled “Lamb Wave Based Tomography for Damage Detection in Aluminium Plates”. The talk was attended by 44 members and it was well received.



Shri Ajay Kumar, CNDTD, VSSC, delivering the lecture



A view of audience

Lamb wave based tomography for damage detection in Aluminium plate

Ajay Kumar, CNDTD, VSSC

1. Introduction:

Among the ultrasonic techniques, Lamb wave have received much attention in the recent years for damage detection. Lamb waves are a type of elastic perturbation that can propagate across large areas of a free-free solid plate with low dispersion of energy, even in materials with a high attenuation. This type of wave was first described in theory by Horace Lamb (1917). It has certain advantages over other techniques. It scans larger area in short period of time and it does not require accessibility of entire portion of the structure to be inspected. Higher sensitivity towards any small change in structural properties and the ability to propagate longer distance makes it very useful to find the defects in large and thin plate like structure.

Lamb wave based damage detection requires expertise in signal interpretation because of its dispersive nature and presence of multiple modes. However, often there is a requirement of a technique which can be implemented and analysed without the help of an expert. In this context, imaging techniques like tomography are found to be much user- friendly. Tomography is the process of making an image of the test specimen by using the propagation

parameters of waves passing through them. Its propagation properties change as it travels through any discontinuity or defects like corrosion, dis-bonds, delaminations, thickness-variations etc. in addition wave passes through the entire thickness of the materials, hence the total cross section is getting inspected.

2. Theory of Lamb wave:

Lamb wave can be considered as a special type of Guided wave whose properties are different from general mechanical wave. They are elastic waves whose particle motion lies in the plane defined by the plate normal and the direction of wave propagation. They are guided by the boundary of the media in which they propagate. It occurs in plate like structure similar to the Rayleigh wave. Rayleigh wave propagates on the surface of the relatively thick solid material whereas Lamb wave propagates through the thickness of the material. It is also known as plate wave and Rayleigh-Lamb wave. Lamb wave has different modes of particle vibration, but there are two most common modes symmetrical and asymmetrical exists as shown in fig. 1.

Lamb waves propagate parallel to the plate faces, and their phase and group velocities are dependent on frequencies and thickness of the plate. Their propagation properties are dependent on the vibration frequencies, thickness and material properties of structure. Their propagation parameters get change after interacting with defects. Flaws like corrosion, disbonds, delamination, air traps act as a change in thickness, and it changes the properties of propagation of the waves. The variation in the properties can be used as a parameter for recognizing the defects.

The Lamb waves can be generated in plates with free boundaries in infinite number of modes, both with symmetric and anti-symmetric modes. These different modes differentiated on the basis of their velocities of propagation in that material at that particular frequency. The symmetric modes have average displacement over the thickness, in longitudinal direction, so they are also known as longitudinal waves, while the anti-symmetric waves have average displacement along the transverse direction, and are known as Flexural waves. It can also be said that symmetric modes have large in plane motion and anti-symmetric modes have out of plane motion. They are represented as S_0 , A_0 , S_1 , A_1 and so forth depending on whether they are symmetric or anti-symmetric. More than one mode can exist at a given frequency of excitation depending on the value of excitation. So the differentiation of each mode is necessary, for the analysis of the received signal, as each mode interacts with defects in a different manner.

Symmetric Lamb waves move in a symmetrical fashion about the median plane of the plate. This is sometimes called the extensional mode because the wave is stretching and compressing the plate in the wave motion direction.

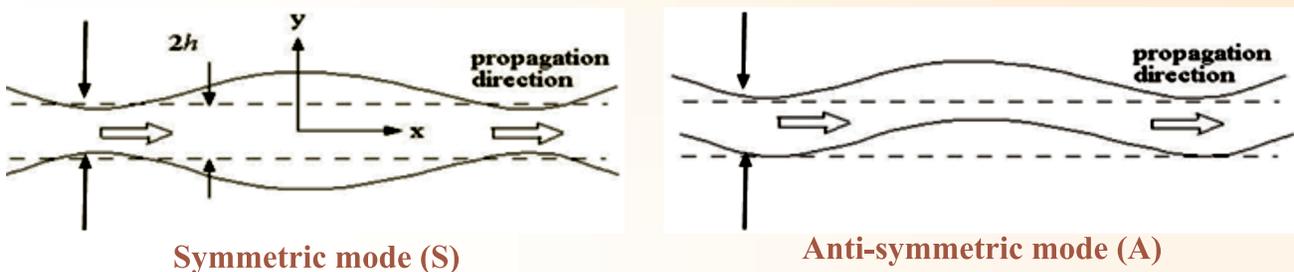


Fig.1 Lamb wave at different mode

Anti-symmetric Lamb wave mode is often called the “flexural mode” because a large portion of motion moves in a normal direction to the plate, and a little motion occurs in the direction parallel to the plate. In this mode, the body of the plate bends as the two surfaces move in the same direction.

3. Tomography:

“It is the process of creating an image of the test specimen using the propagation parameters of wave passing through the specimen”. The Lamb wave velocity is dependent on the modulus of elasticity, density, Poisson's ratio and thickness. So a change in any of these parameters will change the propagation velocity. Also a portion of the wave will get reflected back when the wave reaches a discontinuity. These two behaviours can be used in tomographic reconstruction of image. Here, Time of Flight

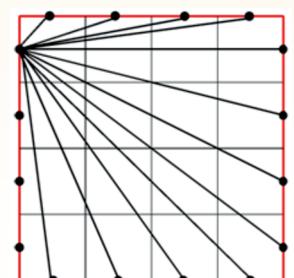


Fig.2 Ray coverage for a 4x4 modified cross-hole array

(TOF) data is considered as input for reconstruction technique to obtain the tomogram. Multiple Algebraic Reconstruction Technique (MART) is used as reconstruction algorithm. The data is collected for each actuator and sensor pair followed by modified cross hole array geometry as shown in fig.2

4. Specimen configuration:

Specimens are made of Aluminium plate of configuration 1.2m x1.2m x1.6 mm. The area of examination is 0.6 x 0.6m². Specimen size is taken sufficiently large to avoid any reflection from the edges. The PZT patches are attached on the Aluminium plate in modified cross-hole geometry. The array is made by placing 8 PZT's equidistantly, on each of the four sides (shown as dot in fig.3). The PZT transducers are of size Ø10 mm x 0.5 mm. It is glued on to the plate using cyanoacrylate based adhesive. The distance between two adjacent PZT patches of a side is 7.5cm. So the plate area is divided into 64 equal areas, as is evident from the fig.3. A defect is created by bonding steel plate of Ø100 mm and thickness 2 mm at centre of the Aluminium plate as shown in fig.3b.

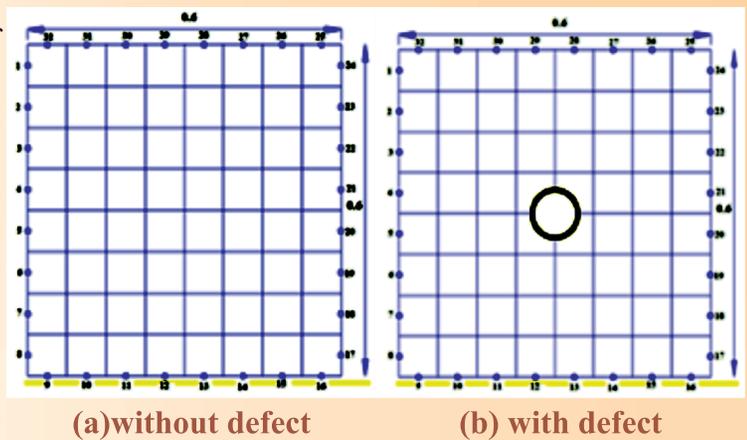


Fig.3. Schematic diagram of specimen with sensor locations shown

5. Finite Element Simulation:

The Lamb wave generation in the Aluminium plate is modelled using ANSYS[®]. The simulation is done in two dimensions (cross-section plane), since the three dimensional simulation would have been costly and time-consuming. The nodes required for three dimensional modelling would be very large and hence the calculation time would also be higher. The element type used are solid PLANE 182. In this case plane strain condition is considered. The size of the element is selected from the relation $L_{max} < \lambda_{min} / \eta_{min}$, and η_{min} is assumed to be 20 to get good convergence. The time step used is based on the relation $\Delta t \leq L_{min} / C$ where C is the wave speed. Using two dimensional modelling the propagation of the wave through the thickness at various frequencies and cycles were studied, and 180 kHz and 5 cycles are chosen for the analysis and experiment. Using the simulated waves, propagation characteristics like Time of Flight (TOF) i.e. time needed for the wave to travel from actuator to sensor, is found out corresponding to each sensor and receiver locations. These values were recorded and given as input to the reconstructive algorithm to make the tomograms. To validate the simulated data experiments were carried out on a defect less Aluminium plate. Further the experiment was carried out on defective plate.

6. Experimental Studies:

The experimental setup to generate and receive Lamb waves on the Aluminum plate is represented in fig.4. The experimental setup consists of a Tektronix AFG 3021B signal generator, a Tektronix TDS 1002B digital storage oscilloscope and a computer connected through a USB interface.

The signal generator is used to generate tone burst in the form of 5 cycles of Hanning window modulated sine wave. The digital storage oscilloscope connected to the computer through the USB interface is used to collect data. The LabView platform controls the output signal parameters and can store the required data for analysis. The Aluminum plate is Al-5052 Aluminum alloy (Young's Modulus=70.3GPa, Poisson's Ratio=0.33, Density=2.68 g/cc).

Initially, the experimental results are validated with simulated lamb wave responses. The velocities of both A_0 and S_0 modes for

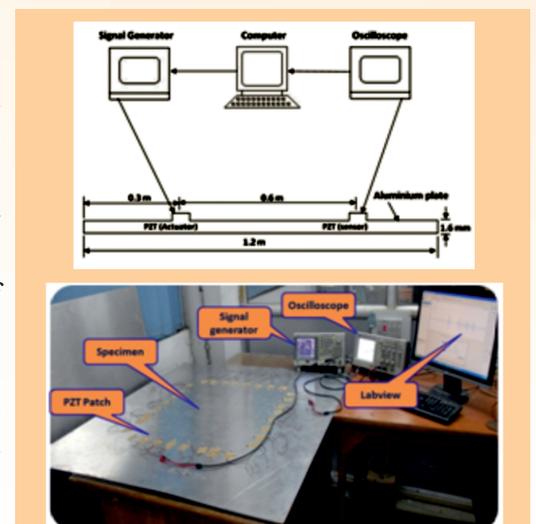
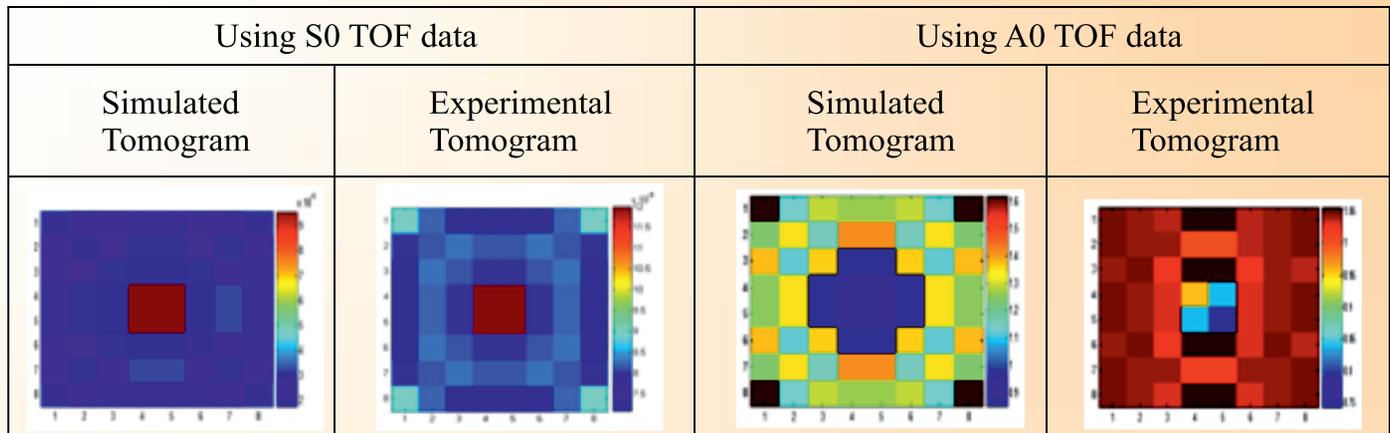


Fig.4 Schematic diagram and photograph of experimental setup

different frequencies of excitation, obtain from experiments and simulations are compared for validation. These velocities match well with error not exceeding $\pm 5\%$. Next, the elastic waves are generated from one of the patches and is detected by all other one. These values were recorded and given as input to the reconstructive algorithm to make the experimental tomograms. Tomogram of defect-less plate and plate with defect are generated.

7. Results:

Tomogram of Defective Aluminium plate using S_0 & A_0 simulated and experimental TOF data



8. Conclusion:

This work has shown that Lamb wave based tomography can be used as convenient method for damage detection in metallic plate. Here, both symmetric and anti-symmetric mode using simulated and experimental TOF data have been used for creating tomogram. Presence and location of defects are clearly visible in all tomograms. The exact shape, orientation, size and severity of defect can be imaged by increasing density of PZT patches. The growing demand of structure with high specific stiffness and specific strength especially in aerospace industry makes us to think beyond metal. This requirement can be fulfilled easily by composites. So there is often a requirement of a fast, reliable and inexpensive NDT method for the inspection of composite structures. Lamb wave based tomography is best suited in this regard. So this Work can further be extended for composite structure.

9. References:

- ❖ Alleyne D. N. and Cawley P, "The Interaction of Lamb Waves with Defects", IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 39, 1992, pp 381–97.
- ❖ Malyarenko E. V., and Hinders M. K., "Ultrasonic Lamb wave diffraction tomography", Journal of Ultrasonics, Vol. 39, No. 4, June 2001, pp 269-81

ATTENTION!

Technical talk

Speaker : **Dr. SVS Narayana Murty**

Materials Characterisation Division

Materials and Metallurgy Group

Topic : Stress Corrosion Cracking

Date : 5/12/2013, Time: 18:30 hrs

Venue : Hotel Nandanam Park

