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ISNT
Non-Destructive Testing

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Image

The Technical Bulletin of
Indian Society for Non - Destructive Testing
Thiruvananthapuram Chapter

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Dear Colleagues,

As we all know that the COVID pandemic has affected the life of all the human being across the world severely. The chapter activities also had an unprecedented interruption due to the lockdown related restrictions. However subsequently COVID has taught us to learn different style of our functioning. Since then we started interacting with everyone even beyond boundaries through online meetings and webinars which attracted more personnel and we do have very good participation than earlier.

Our Chapter had started off this year with two Young Engineers Forum lectures. One was on the latest emerging technique of "Terahertz Imaging" and other one on "Digital Image Correlation (DIC)".

We had resumed Level II Certification Program after a significant gap. The chapter successfully conducted "Training and Certification Programs in LPT and RTFI" on February 2020 under the guidance and support of NCB-ISNT. The course was ably led by Shri. Roykuttan KK and Shri. Raju G with the whole hearted support of the ISNT, Thiruvananthapuram team. The success and overwhelming response of this event has given more confidence for conducting more such certification programs frequently.

Student Chapter activities had started off with a workshop held at Mohandas College of Engineering, Nedumangad. The event was inaugurated by Shri. S Saratchandran with a wonderful inaugural talk on importance of NDE. Two lectures were delivered during the half day workshop which was well received by the student participants and faculties.

Shri. G. Levin, our immediate past Chairman superannuated as DD, SPRE, VSSC in May,2020 after an illustrious career at VSSC. His contributions to ISRO and to ISNT in general and Thiruvananthapuram chapter in particular were phenomenal. Our chapter is blessed to have such veterans and their continuous services to the chapter are valuable assets. After a lull period of four to five months, the chapter resumed its activities by conducting its Young Engineers forum lecture series through Webinar Mode in August 2020 with overwhelming response. The lecture was on "Neutron Radiography" delivered by Shri. Girish N Namboodiri. The Chapter is planning to further conduct such lectures bi-monthly in webinar mode itself.

A student's chapter initiative "Back to Basics" is also being planned where lectures related to basics of NDE techniques shall be delivered to student members. Another Student chapter is planned to be inaugurated at Saint Gits College of Engineering, Kottayam through Online Mode. Level –II programs in UT and Thermography/ Leak Testing are under discussion. SENDAM-2021 is the next big event awaiting us.

NDE 2020 is planned to be conducted in December 2020 through online mode. Request our chapter members to actively participate and contribute in the event by presenting more technical papers.

The chapter activities has to resume normalcy at the earliest with the help of technology since the COVID 19 pandemic may prevail for longer periods. Lots of events are under discussion and I am confident that with the active participation of all our chapter members, we shall achieve greater heights. I also request all the members and their family to follow the COVID-19, break the chain protocols and wishing you all a very happy, healthy and safe life ahead.

Arumugam M
Chairman, ISNT, Thiruvananthapuram Chapter

SECRETARY'S REPORT

(January-August 2020)

The pandemic that affected the entire world affected activities of all professional societies and we were no exception. We were so busy with many events before the pandemic's arrival. The chapter conducted two young engineers forum lecture in January, 2020 followed by a successful Level II certification program on LPT & RTFI on February, 2020. A workshop was organized for the members of Students chapter at Mohandas College in March, 2020. Details of all these events are presented in this issue.

Our activities resumed with an online EC meeting in July followed by Young Engineers forum lecture in August. Our head office's subscription to online platform "Microsoft Teams" helped us to conduct the lecture in a successful manner and more lectures will be arranged in the coming days.

We had two EC meetings in this period and discussed various activities. Feasibility of conducting AGM through online mode was also discussed and EC decided to wait for some more time after discussion with ISNT Head Office. During this period two life members joined us and details are given separately.

New members joined during January 2020 to August 2020

S. No.	Member No.	Name	Organization
1	LM10117TV	Surendran G	LPSC
2	LM10123TV	Ravi Tulsian	VSSC

ISNT Level –II Program on

RTFI and LPT

ISNT, Thiruvananthapuram Chapter conducted Level-II program on Training and Certification Course in Radiographic Film Interpretation and Liquid Penetrant Testing on Feb-17-22, 2020 at ATF area, VSSC, ISRO. The program was inaugurated by Director, VSSC. Shri. S Saratchandran & Shri. G. Levin, Deputy Directors of VSSC and former Chairmen of chapter offered felicitations. Shri. Roykuttan KK, Vice Chairman was the Course Director and Shri. Raju G, VSSC was the Course Coordinator. Director, VSSC also released the course notes for RTFI and LPT.

Both the courses were attended by participants from ISRO centers and external work centers. LPT course was attended by 22 candidates and RTFI course was attended by 26 candidates. Lectures were delivered by eminent people having expertise in relevant areas from ISRO & Outside agencies. Practical sessions were arranged with the help of VSSC resources for the participants. NCB conducted the examinations and 22 out of 26 & 16 out of 22 candidates cleared the exams in RTFI & LPT respectively.

Director, VSSC delivering the inaugural talk

Release of course notes for RTFI and LPT by Director, VSSC

Shri. S Saratchandran, DD, VSSC delivering the lecture on Basics and Significance of NDE

Young Engineers Forum Lecture

Two talks were arranged on 23.01.2020 at Hotel Maurya Rajadhani, Statue, Thiruvananthapuram which was attended by about 50 members. The program was followed by dinner.

1. Digital Image Correlation (DIC) & Stereo Imaging – NDE Capabilities – Part II

The lecture was delivered by Dr. Digendranath Swain, VSSC. This was a second part of the lecture which he had delivered in the previous Young Engineers forum. 3D techniques in DIC and its NDE capabilities were explained in this lecture.

2. TeraHertz Imaging

The lecture was delivered by Dr. Rajeev N Kini, Asst. Professor, IISER, Thiruvananthapuram. The lecture was about the basic principles of Terahertz imaging, latest developments in this area and its various probable applications in the field of NDE in space applications.

ISNT Young Engineers Forum Lecture as Webinar

ISNT Thiruvananthapuram Chapter arranged another Young Engineers forum lecture in its first webinar form due to the prevailing Covid Pandemic Situation on 22.08.2020. A technical talk was delivered by Shri. Girish N Namboodiri, Scientist, NDTF/VSSC on "Neutron Radiography" through Microsoft Teams platform, which was attended by around 90 people. The participants included our chapter members and also few members from other chapters of ISNT.

ISNT Student Chapter Activities

Indian Society for Non-Destructive Testing (ISNT), Thiruvananthapuram chapter conducted a half day workshop on NDE for ISNT student chapter members of Mohandas College of Science & Technology, Thiruvananthapuram on 07.03.2020, Saturday at the college premises. The workshop was inaugurated by Shri. S Saratchandran, DD, SR/VSSC. Lectures were delivered by Shri. Arumugam M, LPSC on "Conventional and Advanced Non-destructive Testing and Evaluation" and Shri. Girish N Namboodiri, Scientist, VSSC on " Advanced NDE techniques and Job Oppurtunites". Around 53 student members attended the workshop.

Shri. Arumugam M delivering the lecture on Advanced NDE methods to the students

Dr. Sivasubramonian B, HOD, MCET presenting a memento to the speaker Shri.Girish N Namboodiri after the lecture

Quantitative Non-destructive Evaluation (Q-NDE) of a Composite Overwrapped Pressure Vessel (COPV) Liner using Digital Image Correlation (DIC)

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ABSTRACT

This paper reports a unique capability of Digital Image Correlation (DIC) for quantitative NDT of mechanical components. A macroscopic defect identified through holographic interferometry on a Titanium COPV liner was re-verified using DIC. Information such as size, strains and displacements at the defect location could be found out to predict the criticality of the defect. These data could be obtained at a test pressure which is 1/24 times the proof pressure of the liner substantiating the NDE capability of DIC. The results show that DIC can be used as a QNDE tool for selective defects.

INTRODUCTION

Non-destructive evaluation (NDE) plays a key role in assessing flightworthiness of modern launch vehicle (LV) and satellite structures. Even though the aerospace designs are flight qualified based on ground based testing, complete reproducibility as the qualified hardware can't be ensured for each flight due to deviations in material and fabrication processes. To overcome such situations, NDE techniques are employed for identifying the deviations and finding their implications in the quality of each component; in totality the reliability of the system. Until now, ultrasonic, radiography, thermography, acoustic emission, eddy-current, magnetic resonance, die-penetration and holography techniques have been widely used for identifying various defects in aerospace subassemblies.

The above techniques provide qualitative information for acceptance of the sub-assemblies based on signatures derived from standard specimens. However, in practice the defects in actual components always cannot be simulated through these standard signatures. Thereby, data interpretation from the above NDE techniques often requires experience of the operator. Moreover, there are possibilities of spurious NDE signals leading to rejection of a defect free subassembly causing loss of economic resources. Furthermore, the NDE data collected from the conventional techniques would not be enough to decide on the remaining strength of the assemblies. Therefore, techniques which can provide quantitative data about the criticality of a defect in terms of the strength of the structure would be of more value, since the residual life can be assessed a-priori. In this context, use of Quantitative-NDE (QNDE) tools which can provide mechanical information such as stress, strains and displacements would be more helpful.

DIC has recently evolved as a reliable technique for measuring displacements and strains in a full field and non-contact manner [1]. This technique have been used world-wide to carry out studies related to experimental mechanics, for example, determination of material properties, crack and fracture studies, and stress concentration effects. After the availability of real-time DIC software, this technique has become even more popular. Recently, DIC has been established as an improved measurement technique for assessing LV structures during structural testing outside the laboratory comforts [3]. Photoelastic coatings also can be used as an NDE tool [5], wherein strain fields can be found out; however, the displacements cannot be measured simultaneously. Similarly, the interferometry based techniques have complex instrumentation and complicated data interpretation requirements, therefore cannot be used flexibly like DIC. An exhaustive review of optical NDT tools can be found in ref. [4].

The possibility of DIC as an NDE tool has been reported in ref. [6, 7] for various applications. Until now, DIC has not been explored as a prospective NDE tool for aerospace and other industries, which is evident from the available literature. In this paper, the potential use of Digital Image Correlation (DIC) as a QNDE tool is reported. A specific case of a composite overwrapped pressure vessel (COPV) metallic liner has been considered for the same. One defect was identified through holographic interferometry which was inspected through DIC. The comparison of displacement and strain field in the defect area and a nearby defect-free location confirms the holographic observations.

EXPERIMENTAL

A typical metallic liner and a COPV are shown in Figure 1. A thin metallic liner shown in Figure 1(a) is normally woven with composite fibres to increase the specific strength. The COPV shown in Figure 1(b) is overwrapped with carbon fibres. The liners are generally fabricated by joining two hemispherical domes at the equatorial plane, which is achieved through a cirseam Electron Beam (EB) welding. Similar welding is also used near the adaptor regions of the liner. The welds being the vulnerable zones for mechanical failures, NDE of these welds are mandatory. Many NDT techniques are used for inspecting the welds and to find-out the defects. Ultrasonic testing and radiography are used as standard NDT techniques to inspect the welds. Holographic NDT (HNDT) is used as whole field method to identify anomalous regions of the entire liner in addition to the welded region. In this paper, holographic interferometry was carried out with pneumatic pressure loading in the levels of millibars and using in-house digital holography software HDigital. A defect was identified for one liner through HNDT, which will be reported in the results section.

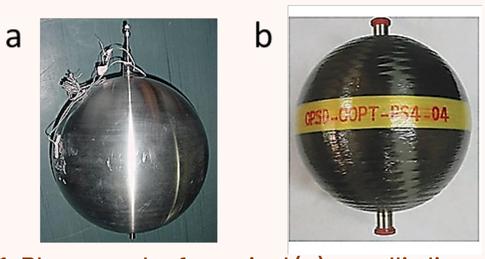

Figure 1. Photograph of a typical (a) metallic liner, and (b) a COPV with carbon fiber overwrapping

DIC is also a whole field technique which would help in assessing any anomalous regions in a whole-field manner. Herein a 3-D DIC set up is used as shown in Figure 2(a). The main requirement of DIC is a random pattern. These patterns are small black and white dots created randomly on the surface of measurement. During the deformation of a component these patterns also deform, thereby it can be used as signal carriers. Generally, the motion of the random patterns is tracked with the use of cameras. Initially, a reference image is captured at zero load. Then the images during the loading sequence are stored. To retrieve the displacements, the images captured during loading are compared with the reference image captured before deformation. Strains are estimated by processing the displacement information.

In this test, a hand pump was used for hydraulic pressurization with a pressure indicator as shown in Figure 2(a). The random pattern generated on the liner is shown in Figure 2(b). The pressurization of the liner was carried out in steps. The sequence of pressurization was 0-2.5-5-7.5-10-12-14-16-20 bars. The displacements and strains obtained through DIC is reported in the results section.

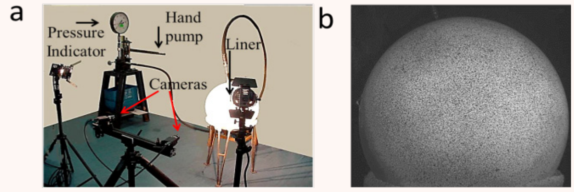

Figure 2. (a) DIC test setup inside laboratory with a hand-pump and pressure indicator, and (b) image of the random pattern generated on the liner.

RESULTS AND DISCUSSION

A sketch of the liner is shown in Figure 3(a), where the location of the EB weld on the equatorial plane is depicted. The fringe pattern, which represents contours of out of plane deformation have been obtained through holography at a defect free location on a liner as shown in Figure 3(b). Normally, the liners are fully scanned with holographic interferometry for identifying any anomalous locations. During scanning of the same liner a defect was seen above the EB weld on the parent material as shown in Figure 3(c). The anomalous fringe pattern in Figure 3(c) shows high local radial deformation which is evident from the higher fringe density. The fringe pattern is able to identify the location of an anomalous region; however it cannot provide quantitative information such as displacements or strains. Thereby, the criticality of this defect cannot be found out from the available qualitative information.

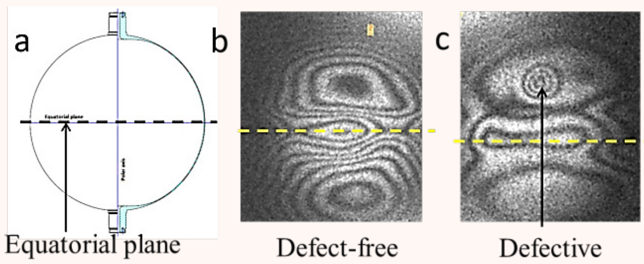

Figure 3. (a) Line diagram of a liner showing the equatorial plane, where two domes were welded together, (b) holographic fringe pattern of the liner showing a defect free zone, and (c) an identified defective zone. The dashed lines shown here is the EB weld location.

The defect identified through holography is again inspected using DIC for obtaining mechanical information; such as displacements and strains. An area of interest (AOI) containing the anomalous region was imaged and analyzed using VIC-SNAP and VIC-3D [2]. The displacement and strains obtained in the AOI would be discussed below.

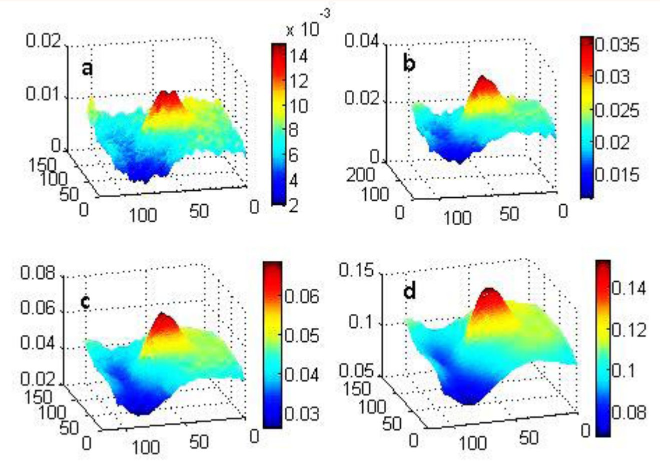

Figure 4. The 3-D surface plots of the radial displacements in the AOI at (a) 2.5 bar, (b) 5 bar, (c) 10 bar and (d) 20 bar pressure are shown.

The 3-D surface plots of the full-field radial displacements in the AOI are shown in Figure 4 at different pressures. A contour plot of the radial displacement is also shown in Figure 5(a). These plots clearly indicate higher displacements at the anomalous region as compared to the defect free locations which confirms the inference through holography. The smallest deformation in the AOI occurs at the EB weld which was thicker than the parent material where defect was identified. Such observations however were not seen in the hoop and meridional displacements, hence are not shown here.

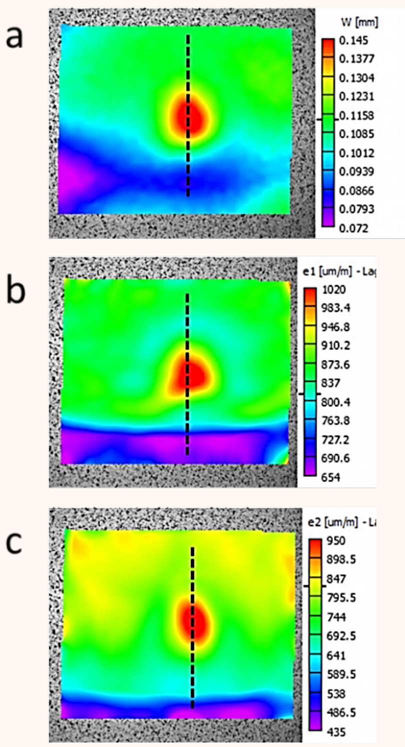

Figure 5. The 2-D contour plots of the (a) radial displacements, (b) major principal strains, and (c) minor principal strains at 20 bar pressure are shown.

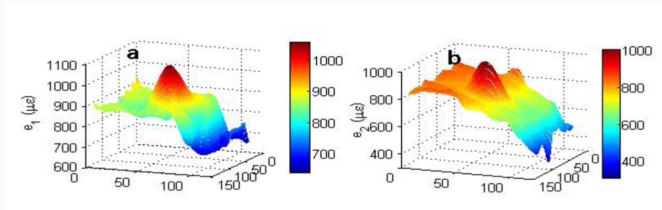

Figure 6. The 3-D surface plots of the (a) major and (b) minor principal strains in the AOI at 20 bar pressure are shown.

The anomaly in the displacement field would definitely influence the strain field. The full-field contour plot of the major and minor principal strains obtained at 20 bar pressure are shown in Figures 5(a) and (b), respectively. The 3-D surface plots for these are shown in Figures 6(a) and (b). It is possible to infer from these plots that the anomalous region have higher strains than the surrounding region. Therefore, the data obtained can tell about the criticality of the defect at this stage by comparing the mechanical strength or more specifically yield strength of the liner.

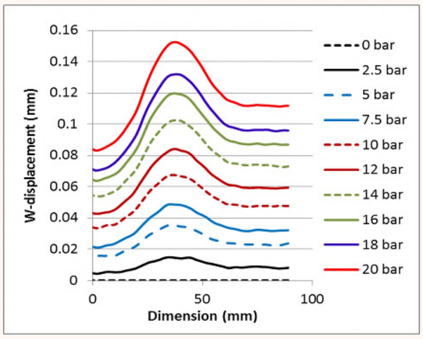

Figure 7. Variation of radial displacement along a vertical line as shown in Figure 6 throughout the pressurization.

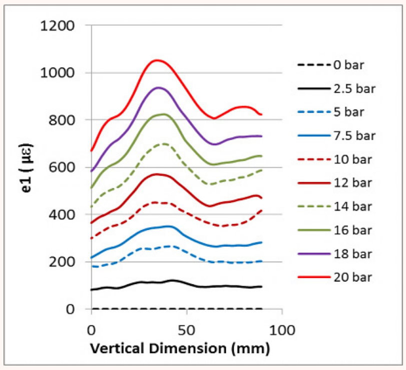

Figure 8. Variation of major principal strain along a vertical line as shown in Figure 6 throughout the pressurization.

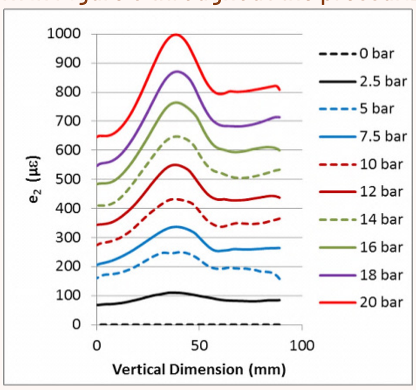

Figure 9. Variation of minor principal strain along a vertical line as shown in Figure 6 throughout the pressurization.

Until now the displacement and strain data at discrete pressure steps have been discussed. The detailed radial displacement, major principal strain and minor principal strain throughout the pressure cycle are shown in Figures 7, 8, and 9, respectively. The variation of these parameters along a vertical line passing through the defect as shown in Figure 5 are reported. The zero datum in the vertical dimension is the location on the equatorial EB weld. The dimension increases towards the pole. It can be observed from Figure 7 that the anomaly in the radial deformation could be found at an earlier stage i.e.at 2.5 bar pressure itself, where the defect had deformed by 6 μm more than a representative surrounding defect-free location. Such higher accuracy displacement measurement is very encouraging, since defects generally show such kind of behavior. The strain anomaly at the defect location also could be captured at 2.5 bar pressure. However, a clear demarcation in the full-field plot could be seen only at 5 bar pressure, which was somewhat higher than the pressure required for obtaining an anomalous displacement field. The defective region showed 20 and 50 microstrains higher strains than the surrounding location at 2.5 bar and 5 bar pressure respectively. Such finer changes in the strain field which could be captured with DIC is also very encouraging. It can be noted here that the proof pressure of these liners is 60 bar. It means that the anomalies could be captured at a pressure 12 times lesser than the proof pressure. Therefore, the pressurization cannot damage the liner and its functionality. These inferences show that DIC can be utilized as a QNDT tool for mechanical designs.

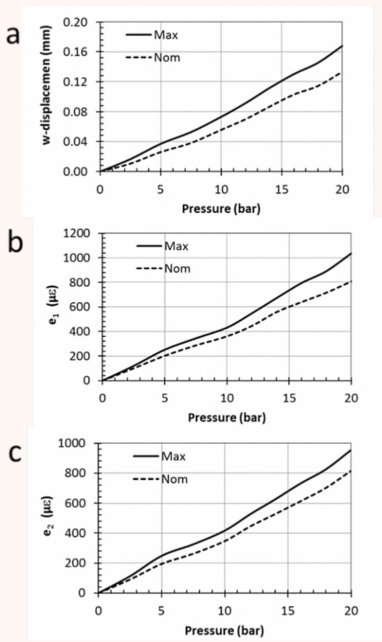

Figure 10. The variation of (a) radial displacement, (b) major principal strain, and (c) minor principal throughout the loading are shown.

Even though the anomalous region could be identifed at the lower pressures, the liner was loaded up to 20 bar pressure to fetch additional information. With increased pressurization the defect became more visible from the surroundings as seen from Figures 7, 8, and 9. This increased pressurization created strains of the order of 1000 micro-strains and displacements of the order of 150-170 μm at the defect location at 20 bar pressure, which were 230 micro-strain and 35 μm higher than a representative non-defective location. The displacement and strains at the defective location as compared to a nearby non-defective location throughout the pressurization can be seen in Figure 10. The strains obtained herein is well below elastic limit. Therefore, the curves are linear. However, the trends in Figure 10 show that the gap between the parameters keep on increasing with increased pressurization. Therefore, strains beyond the elastic limit at the defect location would be crucial and an initiation of local failure cannot be avoided at this location.

CONCLUSION

The strains measured were found to be within elastic limit and the applied pressure was less. Thereby, the evaluation carried out with DIC conforms to the NDE requirements. Moreover, the high spatial resolutions in displacement and strains seen from the results qualify it to be a sufficiently sensitive tool for defect detection. It would be more resourceful to use DIC as a secondary level tool for obtaining 1:1 quantitative information about defects, when there are ambiguities in the results from the regular NDE tools. The case study shown herein is such an illustration. It seems that DIC can be used as a prospective QNDE technique for LV structures. The evaluation of micro-defects, which cannot reflect any anomaly in the surface displacement or strain field, would be limited through DIC, which requires micro-structure detailing.

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From The Editor

Dear ISNT fellow members,

We started this year with new hopes and aspirations. The global pandemic COVID-19 has made unprecedented modifications to the normal life of everyone. After recovering from the initial shock and confusion, we have started to adapt to the reality. Initially, we thought of returning to normalcy in a short span of time. We soon realized it was not to be so and then started learning to 'live with the virus'. Masks, hand sanitisers and social distancing became the order of the day. In our professional lives too, the changes forced by the virus has been substantial. We may have to wait for some more time for returning back to our conventional technical meetings, seminars and conferences. But mankind had been facing challenges and has been constantly finding alternative ways to survive. We have quickly tuned in ourselves to the digital and online platforms for technical interactions. Seminars have changed to webinars and online conferences and training sessions have started. We have even discovered some advantages like cost reduction, less travel and more participation from home. We need to continue our professional activities by resorting to new methods and using new platforms. Students are continuing their education through online media now; our student outreach programmes and training shall also be integrated to this effectively.

Digital Image Correlation (DIC) for quantitative NDT of mechanical components is an exciting topic. Of late, this technique has evolved as a valuable tool in assessment of critical launch vehicle structures during structural testing. In this edition, we have an interesting article in which the author explains how a macroscopic defect identified through holographic interferometry on a Titanium composite overwrapped pressure vessel (COPV) was re-verified using DIC. From the results, it appears that DIC is a promising secondary level tool for obtaining quantitative information about defects. We request our members to contribute similar articles on new techniques and applications of NDE.

NDE-2020, the flagship event of ISNT is scheduled for the end of the year. Active participation from all our members is solicited.

Stay safe following all the precautionary measures. We shall tide over these difficult times soon. Nothing lasts forever.

With best regards,

MOHAN KUMAR.L
CHIEF EDITOR

Image

Published on behalf of Executive Committee, **ISNT Thiruvananthapuram Chapter.**

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