Indian Society for ISNT Non-Destructive Testing

April - July 2019

Image

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

www.isnttvm.org

From Chairman's Desk...

Dear Friends,

I am delighted to communicate to our beloved members through Image, the last edition of present EC. It has been a wonderful two years for the entire committee with many events organized successfully in spite of tight official engagements. It has been great working with the team of enthusiastic members. I appreciate the efforts put by each and every member of ISNT Thiruvananthapuram chapter.

Personally for me, it has been an exciting experience and gave me immense pleasure in leading the chapter for the past four years. I am really happy that most of targets we set are materialised with the whole hearted support and the hard work put in by many of you. I sincerely thank each one of you for the tremendous support .

ISNT Student Chapters are formed at various colleges in Thiruvananthapuram and many programs were successfully conducted in these colleges. The chapter had tried to spread the knowledge in the NDT area to young minds through various programs conducted in association with these student chapters. The huge knowledge resource from ISRO NDE community had been tapped effectively to conduct these programs.

Young Engineer's Forum had conducted several lectures which provided the Young Scientists a platform to present their research works in front of a team of experts in the area.

I am happy to inform that our long standing dream of having a separate office for the Chapter also came to reality in this tenure. GST registration for the chapter is in progress. The Image team has been very active and brought issues on a regular basis especially at all important occasions. Shri. Mohan Ananthanarayanan ably guided the team and Shri. Girish N Namboodiri excelled in the responsibility of co-editor. All the issues carried latest updates, technical articles and some basic information on NDE.

I am extremely happy to announce the success of the much awaited biennial event "Seminar & Exhibition on NDE & Allied Methods-SENDAM-2019" with the Theme: 'Advances in NDE & Metrology' held at VSSC during 24th & 25th May 2019. A detailed report on SENDAM is included in this issue.

Young team of SENDAM rose to occasion at various instants that made the event much more exciting. Right from the organising stage, the team faced lot of challenges. But under the brilliant leadership of Shri. Arumugam M, Chairman, SENDAM 2019, the team had managed to get over each difficulty and came up in flying colours. Kudos to each and every member of team SENDAM 2019. The tremendous success gives me hope that we can sustain and scale greater peaks in the coming years.

A strong platform had been laid and the momentum the present EC had brought about is to be transferred to the next team. I am having great faith on the entire team and pretty sure that the next committee would take the chapter to higher heights.

Wishing you all the best,

G. Levin,

Chairman,

ISNT, Thiruvananthapuram Chapter

Secretary's Report
April - July 2019

Inside Executive Committee

The Executive Committee had three formal meetings during this period. ISNT DAY 2019 was celebrated on 23.04.2019 by ISNT Thiruvananthapuram Chapter at Hotel Chirag Inn in a grand manner. Shri. G Levin, Chairman ISNT Thiruvananthapuram Chapter& Deputy Director, SPRE/VSSC has inaugurated the program. Shri. Arumugam M, Vice Chairman, ISNT Thiruvananthapuram Chapter & Group Director, Quality control and NDE group, LPSC, Valiamala had delivered a talk on 'Computed Metro tomography for NDE and Metrology'.

Two days Seminar and Exhibition on NDE and Allied Methods (SENDAM - 2019) was conducted on 24th & 25th May 2019 at VSSC, Thiruvananthapuram. The theme of the seminar was Advances on NDE & Metrology. The seminar had two parallel sessions; one each on NDE & Metrology. Overall 18 lectures were delivered over two days. All the lectures were delivered by eminent personalities in both the fields from ISRO, Equipment suppliers and Professors. A total of 120 delegates attended the seminar along with considerable number of sponsors and exhibitors. There were 16 stalls in the exhibition by leading national/ international suppliers of NDE & Equipment manufacturers.

Rajadhani College of Engineering, Attingal, in association with ISNT, Thiruvanathapuram Chapter had conducted a Faculty development program on 8-10 July 2019. Lectures covering the basics and advancement of NDT were delivered by the NDT experts from ISNT, Thiruvananthapuram chapter.

ISNT, Thiruvanathapuram chapter has taken office room on rental basis at Karuna complex, near Stationkadavu, Kazhakoottam. The registration activities are in progress for obtaining the GST registration. Executive Committee decided to conduct the Annual General Body Meeting 2019 and MR Kurup Memorial lecture of our chapter on 20th July 2019. ISNT, Thiruvananthapuram chapter has introduced awards as a part of recognition of its members for their outstanding contributions in the field of Non-destructive testing from 2019 onwards. It is planned to distribute these awards during the Annual General Body meeting of ISNT, Thiruvananthapuram chapter.

The Chapter Vice Chairman, Shri. Arumugam M had delivered an invited talk on "Computed Metro Tomography is an asset for Aerospace Applications" at 16th Industrial X-ray & CT Forum 2019 at Hannover, Germany.

Shri. Arumugam M,
delivering invited lecture at Hannover, Germany

ANNUAL GENERAL BODY MEETING

Date & Time : **20th July 2019 (Saturday) at 5. 00 pm**

Venue : **Hotel Classic Sarovar Portico, Manjalikulam road, Trivandrum**

Highlights of the Program :

M. R. Kurup Memorial Lecture
Speaker : Shri K. Viswanathan
(Deputy Director (Rtd.),SDSC, SHAR)
Topic: Challenges in NDE of Indian Space Programme

Annual technical lecture :
Speaker : Dr. S Krishnan
(Ass. Prof. of Psychiatry, Govt. Medical College, Tvm.)
Topic:Stress Management

Felicitations to :

Dr. V P Mahadevan Pillai ,
Vice Chancellor, Kerala University

Shri. Arumugam M,
Group Director, LPSC

Distribution of ISNT Thiruvananthapuram Chapter Awards 2019 & Annual General Body Meeting

ISNT DAY CELEBRATION BY ISNT THIRUVANANTHAPURAM CHAPTER

ISNT DAY 2019 was celebrated by ISNT Thiruvananthapuram chapter at Hotel Chirag Inn in a grand manner on 24/04/19. Shri A Shunmugavel, Former Secretary briefed about the significance of the celebration. Shri G Levin, Chairman, ISNT Thiruvananthapuram chapter & Deputy Director, VSSC inaugurated the programme. In his inaugural address, he mentioned about the objectives of ISNT and recalled the efforts of the society for the last 20 years towards promotion of scientific development in the area of non-destructive evaluation and quality consciousness. He appreciated the efforts taken by all chapter members comprising of eminent personalities in NDT field and young talents who volunteer themselves to take over the challenges in organizing events to propagate the knowledge of NDE. He proudly informed about the importance given by our chapter to the technical content in any programs organized. Shri Arumugam M, Vice Chairman, ISNT Thiruvananthapuram Chapter & Group Director, Quality Control and NDE group, LPSC, Thiruvananthapuram delivered a talk on 'Computed Metro tomography for NDE and Metrology'. The lecture was loaded with comprehensive technical information about CT, the results of studies carried out at ISRO and the features of latest equipment purchased by LPSC, Thiruvananthapuram. The interactive lecture was well received by the participants and further raised the curiosity of the participants about CT. The programme was followed by dinner.

Shri G Levin,
Chairman, ISNT Thiruvananthapuram chapter inaugurating the ISNT Day celebration

Shri Arumugam M,
Group Director, LPSC, Thiruvanathapuram delivering talk on Computed Metro tomography for NDE and Metrology

Dr. R M Muthiah,
VSSC (Rtd.) giving memento to **Shri Arumugam M**

Participants for the ISNT Day 2019 celebrations

Seminar and Exhibition on NDE & Allied Methods - SENDAM 2019

ISNT, Thiruvananthapuram chapter has organized a two days Seminar and Exhibition on NDE and Allied Methods (SENDAM - 2019) on 24th & 25th May 2019 at VSSC, Thiruvananthapuram. The theme of the seminar was Advances on NDE & Metrology, two major pillars of Quality Control. The seminar theme was chosen as an enabler of Absolute Quality Program launched by ISRO.

The seminar was inaugurated by Shri S Somanath, Director, VSSC at Dr. Srinivasan Auditorium on 24.05.19 at 09.15 hours and he delivered the inaugural address sharing his experiences highlighting the significance of NDE & Metrology. Souvenir of the seminar was released by Dr. V. Narayanan, Director, LPSC and he offered felicitations. Shri D Sam Dayala Dev, Director, IISU offered felicitations at the inaugural function and he inaugurated the technical exhibition of NDE & Metrology equipment suppliers organized at ATF area. Director, VSSC & Director IISU showed keen interest on the latest products at display and spent valuable time at each stall to know more details and informing them of the demanding challenges of space arena. Dr. S.K. Jha, Director, P&M, Midhani delivered the key note lecture at the inaugural function. Website of NDE 2019, to be held at Bangalore was also launched by Director, VSSC at the inaugural function.

The seminar had two parallel sessions; one each on NDE & Metrology. Overall 18 lectures were delivered over two days. All the lectures were delivered by eminent personalities in both the fields from ISRO, Equipment suppliers and Professors and the speakers included Dr. Zacher, GE, Germany and Prof. Radhakrishnan, Retd. (IITM). The spectrum of lectures covered all the latest advancements in each field. All the lectures were well received by the delegates and same was evidenced by the feedback received.

A total of 120 delegates attended the seminar along with considerable number of sponsors and exhibitors. There were 16 stalls in the exhibition by leading national/ international suppliers of NDE & Equipment manufacturers. All exhibitors were kept busy throughout the seminar by enthusiastic delegates and overall satisfaction level was overwhelming especially on the technical knowledge enrichment. A cultural evening with dinner was arranged for the participants on first day at Hotel Classic Sarovar Portico with an enjoyable music fest by SEA orchestra team.

The seminar received tremendous positive feedback from all participants, which gives TEAM SENDAM the confidence to comeback stronger in future.


SENDAM 2019
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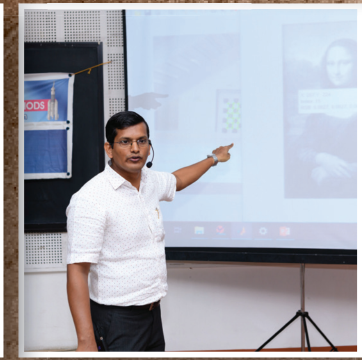


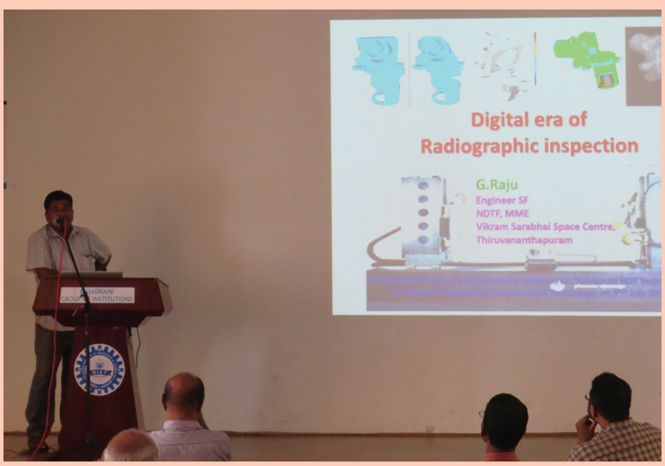

SENDAM 2019
SEMINAR & EXHIBITION ON NDE & ALLIED METHODS

Faculty Training Program at Rajadhani College of Engineering, Attingal

Rajadhani College of Engineering, Attingal, in association with ISNT Thiruvananthapuram Chapter had conducted a Faculty development program "Advanced Non-Destructive Testing Techniques" on 8-10 July 2019. Lectures covering the basics and advancement of NDT were delivered by the NDT experts from ISNT Thiruvananthapuram chapter.

Inaugural Function at Rajadhani College of Engineering, Attingal

Shri. Roykuttan K K, VSSC delivering a lecture on Radiography Techniques



Shri. Raju G, VSSC delivering a lecture on Digital era of radiographic Inspection

Distribution of certificates by Shri. S Sridhar, VSSC

Digital Image Correlation (DIC) – An Invaluable Tool for Non-contact and Full-field Assessment of Critical Regions on Launch Vehicle Structures

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ABSTRACT

This paper reports the use of Digital Image Correlation (DIC) as an improved tool for structural assessment of critical locations on launch vehicle (LV) sub assemblies. Mainly, the in-depth understanding of structural response to static loads at complex and critical regions can be obtained in a full-field and non-contact manner. Four case studies showing the full-field strains at stress raisers in various sub assemblies of rockets and LVs are presented. The linearity of peak strains during the loading cycles are reported which provides information about yielding or any trend changes during the loading.

INTRODUCTION

Digital Image Correlation (DIC) [1] is a state-of-the-art technique for measuring displacements and strains in a full field and non-contact manner. This technique has been exploited world-wide to carry out studies related to experimental mechanics, e.g. measurement of material properties, fracture,stress concentration and so on. With the availability of real-time DIC software [2], this technique has become even more popular. This paper reports the use of DIC for in-situ and remote assessment of critical locations of large launch vehicle (LV) sub-assemblies during ground-level structural testing. The usage of DIC for structural assessment of LV components during structural testing outside the laboratory comforts is one amongst the few attempts made until now. Moreover, ability of DIC as an improved measurement tool during structural testing has been established.

In LV components, features such as cut-outs, corners, thickness transition zones, notches are inevitable for functional requirements. However, these provisions make the structure or component vulnerable for stress concentration [3]. Therefore, the criticality of these stress raisers has to be assessed through some measurement tools before flight. Strain gauges (SG) are used exhaustively for structural assessment during ground-level testing. Since, SGs are single point based measurement tools; the exact location of the critical location has to be known apriori. Even though FE analysis is carried out to predict the critical locations, minute local detailing of the FE model is generally not carried out for large structures. Hence, identification of the exact location of the stress concentration is a very difficult task. Therefore, many SG have to be mounted near the predicted critical regions to capture the stress concentration, which cannot produce meaningful data.Because the stress concentration occurs in a very smaller region; the gauge length (GL) available in SG would produce averaged strains. The measured strains may not represent the actual peak strains. Furthermore, the maximum range of strain measurement in SG is limited to 4%, after which it gets debonded; unless special gauges and bonding techniques are resorted to. Additionally, the critical locations often have less width of materials available, where mounting a strain gauge is not feasible. The above mentioned problems can be alleviated by using whole-field techniques, as whole-field measurements would assist in viewing the distribution of strain and displacement around a larger area. Thereby it assists the design teams to identify and assess the critical locations on a structure.

Many optical whole-field techniques are available for monitoring critical regions, e.g. photoelasticity and interferometry based methods [4-5]. Photoelastic coatings can be used for whole-field strain measurement [5]; however, the displacements cannot be measured concurrently. The interferometric tools have complex instrumentation and data interpretation requirements[4]. Moreover, the measurement ranges are also limited. They are mostly suitable for studies involving micro level motions. Therefore, these techniques cannot be used as in-situ and remote monitoring tools, especially when the tested structures undergo large motions. DIC fulfills all the requirement of an in-situ and remote monitoring tool as it can provide displacements and strains from a single analysis. DIC has very high spatial resolution of the order of 50 μm/pixel in an area of 100 mm × 100 mm, when the camera resolution is 4 million pixels. DIC can quantify the smallest (1 μm) to the largest displacements (100 mm) possible during a structural test. These flexibilities available in DIC can be utilized as an improved method of assessing a structure.

In this paper, four case studies highlighting the assessment of various stress raisers during structural testing of LV components carried out in the authors' organization are reported. A thickness transition zone of a gas bottle liner, a flanged corner of cryogenic engine thrust frame, a small V-notch interacting with a rectangular cutout in a separation system of a sounding rocket, and cut-out to hole interaction on an interstage have been assessed using DIC. In these cases, the regions of peak strains have been identified, and their response during the loading has been quantified, which provides information about phenomena such as yielding and trend changes during loading.

DIC IN BRIEF

DIC is an image vision technique where identification of the motion of particular template is carried out automatically. Automatic pattern or feature matching in image pairs has been a challenging task until now, since it is very hard to conclude which kind of pattern produces best results. In the illuminating monograph by Sutton [1], he calls these patterns as surface textures. For a best match, he advocates the use of an isotropic and non-periodic pattern. Thus the patterns used in DIC have been famous as random speckle patterns. A key property of random pattern is that they act as signal carriers. Since, the random pattern is available everywhere on the surface, relatively smaller areas can be chosen for pattern matching known as subsets. A typical random pattern is shown in Figure 1(a).

An image pair is necessary for extracting motion related information. The digital image used for selecting the subsets is known as the reference image (zeroth image). Now, the subsets selected in the reference image are unique finger prints which have to be searched in target images, known as deformed images using a correlation algorithm. Therefore, the name Digital Image Correlation (DIC). During a mechanical test a sequence of images are often taken at different load/time intervals to capture the time and load related mechanics of the targeted object using a certain correlation algorithm. The algorithm used in the current study is known as Normalized Sum of Squared Difference Criterion (NSSD). For template matching generally a correlation coefficient is used for estimating the degree of matching expressed as [1]

$$R^2 = \sum\left(\frac{\sum F_i G_i}{\sum G_i^2} G_i - F_i\right)^2$$

where, F_i are the grey values of each pixel inside the reference subset and G_i are the grey values of each pixel inside the deformed subset.

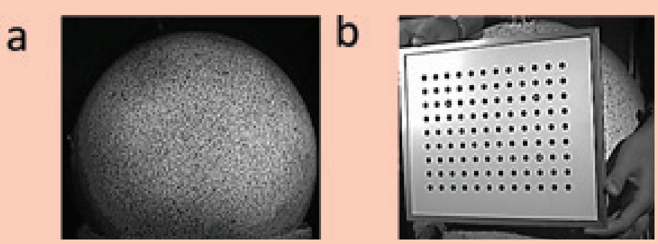


Figure 1. (a) Random pattern generated on a typical component, and (b) a typical calibration grid used for stereo calibration in 3-D DIC.

Two versions of DIC are available, namely 2D-DIC and 3-D DIC. 2-D DIC makes use of a single camera and the experiments are simple; which suits for studying in-plane mechanics. However, when out-of-plane motion occurs 2-D DIC cannot produce accurate displacement and strain data. Therefore, 3-D DIC is used during studies with three dimensional motions on any kind objects. A typical 3-D DIC set up is shown in Figure 2. It can be seen that two cameras in a stereo arrangement is stationed for imaging the random patterns on a specimen surface. The 3-D DIC setup more complex than a 2-D system as stereo calibration is involved. The stereo calibration helps in constructing a 3-D co-ordinate system considering the camera parameters. This is an essential step in 3-D DIC, which is carried out using a calibration plate as shown in Figure 1(b).

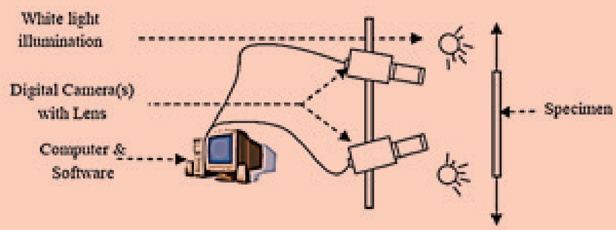


Figure 2. A 3-D DIC test setup showing the various instruments used.

The step-by-step procedure followed for a DIC test is given below:

1. Generation of random speckle patterns
2. Stereo arrangement of camera, optics and illumination.
3. Camera calibration of the stereo rig to obtain the necessary stereo-camera parameters such as base line distance, stereo, pan and tilt angles.
4. Reference image grabbing. Once reference image is grabbed the setup must not be disturbed.
5. Capturing of deformed images during the loading
6. Calculation of the displacements and strains using a correlation algorithm. In the present work, software 'VIC 3-D' [2] has been used.

RESULTS AND DISCUSSIONS

The results for four case studies as mentioned earlier would be presented here. Each case being distinct from each other, the article shows five real cases of stress concentration in LV structures. In each case the difficulties faced are highlighted.

CASE-1: THICKNESS TRANSITION ZONE

In LVs and satellites,thin spherical pressure vessels known as liners are used for storing high pressure gases or liquids after over wrapping with composite fibres. The typical design involves some thickness transition zones near the poles (location A) and the equator (location B) as shown in Figure 3. Under hydrostatic pressure the vessel dilates which induces some membrane bending near the thickness transition zones. Thereby, the designers predicted that the stress concentration would happen in this location. Until the availability of the DIC system in VSSC, SGs have been used to measure the strains point-wise. The SGs could not provide the full-field distribution of the strains, even though they were providing the trend of the strain variations. Moreover, the SGs were mounted at designated angles, where the peak strain would not have occurred.

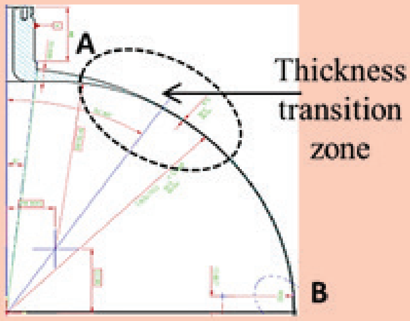


Figure 3. A line diagram of a quarter of a liner showing the thickness transition region near the pole.

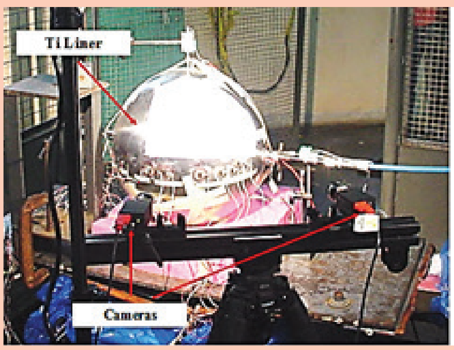


Figure 4. DIC test setup during the proof pressure testing of a gas bottle liner.

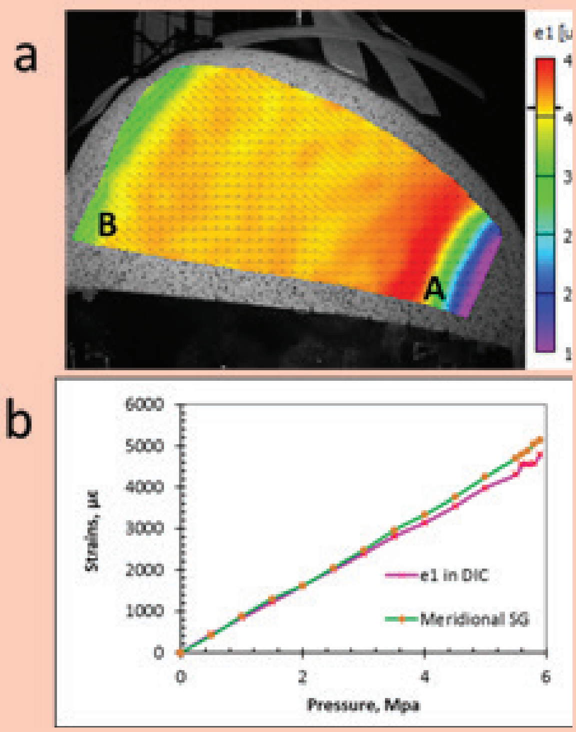


Figure 5. (a) Full-field meridional strain plot at 6 MPa pressure, and (b) comparison of strain gauge and DIC data at one strain location.

The test setup for DIC during proof pressure testing of a liner is shown in Figure 4.The full-field meridional strain plot for one sector of the liner is shown in Figure 5(a). It can be seen that peak strains occur at the thickness transition zone near to location A. The lower strain occurs at the pole at A and the uniform thickness regions show uniform strains as evident from Figure 5(a). The strain data obtained with DIC is compared with one of the strain gauges pasted nearby as shown in Figure 5(b). Both measurements were very close, which validates the DIC measurements. Therefore, peak strain at the transition zone was found to be 0.0048 which was perfectly linear throughout the pressurization.

CASE-2: A SHARP CORNER

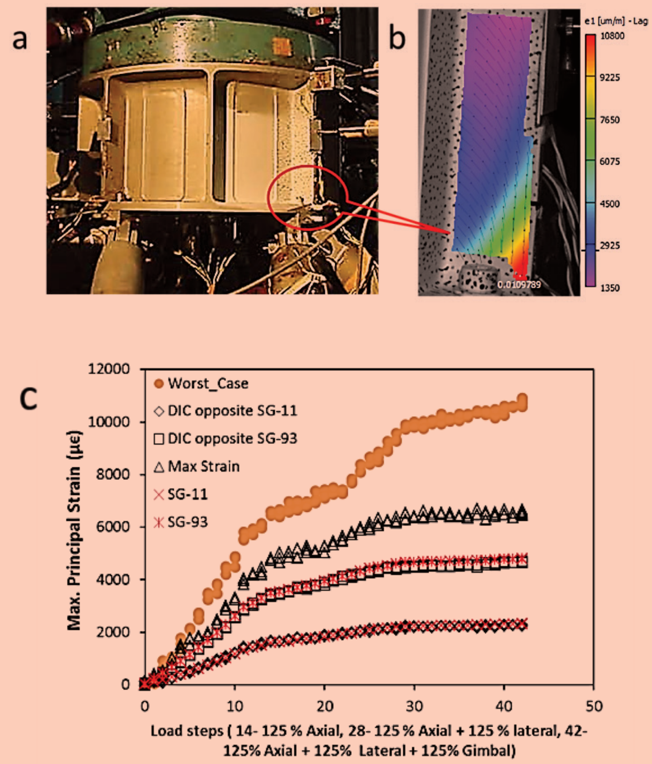


Figure 6. (a) Photograph of the cryogenic thrust-frame fore-end ring showing a sharp corner at the flanged, (b) the full-field strain plot for the worst loading is shown, and (c) comparison of SG with DIC at a less sever load is plotted with the strains due to a severe loading case.

It was expected through FE analysis that one corner of a web at the fore-end ring of a cryogenic-engine thrust frame (Figure 6(a)) to have large strains due to the critical loads. The sharp corner was obstructed by a bolt for optical access. The DIC measurement was taken at the smallest width available after this obstruction. During trial testing, a strain gauge mounted near to the corner showed very less strain. Afterwards, DIC was used on the opposite side of the SGs to see the full-field distribution of strains near the corner and obtain peak strains. Figure 6(b) shows that strain is localized to a small area near to the corner. The loading case consisted of combination of all the loads acting on the thrust frame. Initially, axial compression was applied, then lateral load was applied, finally the gimbal load was applied. Thereby, the trends change in the strain plots at different steps, which can be seen in Figure 6(c). Figure 6(c) also shows the comparison of the SG and DIC data at the qualification load (lesser than the ultimate load). The DIC data were extracted from the SG location but on the opposite side of the web. The DIC data are closely matching with the SGs, which again validates the DIC measurements. Furthermore, the peak strain at the sharp corner at the qualification load shows higher values than the SG values. Subsequently, the structure was loaded for its ultimate load, the strains obtained at the corner is again shown in Figure 6(c). It can be seen that the peak strain is around 0.011, which has gone beyond the yield limit of 0.007. Thereby, the structure should have locally yielded.

CASE-3: NOTCH & CUTOUT INTERACTION

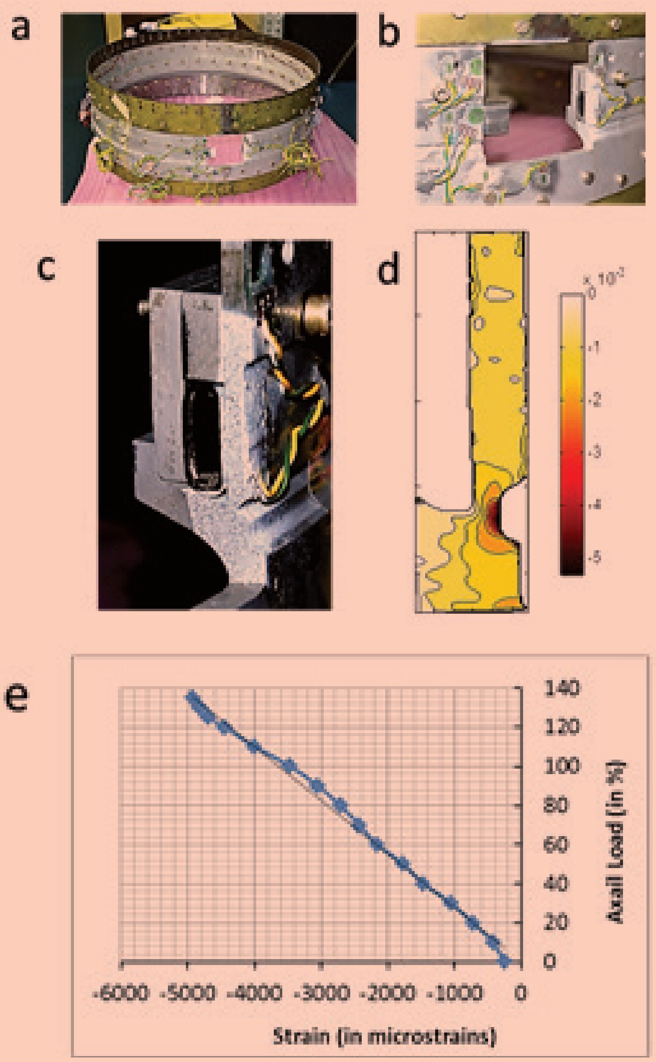


Figure 7. (a) Image of the frangible ring showing the cut-out, (b) a close-up view of the cutout showing the interaction of the cutout and the notch, (c) the area which was monitored during structural testing, (d) the full-field strain plot at the notch-tip, and (e) load versus strain plot during the test.

The Expandable Tubular Assembly (XTA) separation system was configured for an advanced rocket to separate burn-out stages. The XTA system was configured in a frangible ring as shown in Figure 7(a) and (b). The frangible ring was having a square cut-out for functional requirements such as access to electronic packages. In the meanwhile, a V-notch was configured on the outer periphery of the frangible ring (Figure 7(c)) as a part of the XTA to assist smooth separation. The design became critical due to the interaction of the stress concentrations due to notch and the cut-out, which were at two different planes. It was necessary to measure the peak strains at the notch tip to ensure that the design was safe. The base of the notch was having 2 mm of material left, where mounting strain gauge was not feasible. Therefore, DIC was chosen to find out the peak strain as well as the strain distribution. The full-field strain distribution at the maximum load is shown in Figure 7(d). The peak strain during the loading is plotted in Figure 7(e). Figure 7(e) shows a linear trend of strains throughout the loading with the maximum strain recorded as 0.005. This means the notch was under pure elastic influence and hence the design was found to be safe. A plastic yielding behaviour was predicted through FEA prediction for this case, which could not be observed through DIC.

CASE-4: CUTOUT & HOLE INTERACTION

Like the previous case, the interstage of LVs is accommodated with large rectangular cut-outs for accessing the electronic units and manual access for rectifying or assembling smaller components. These cutouts are covered with cover plates before the flight.

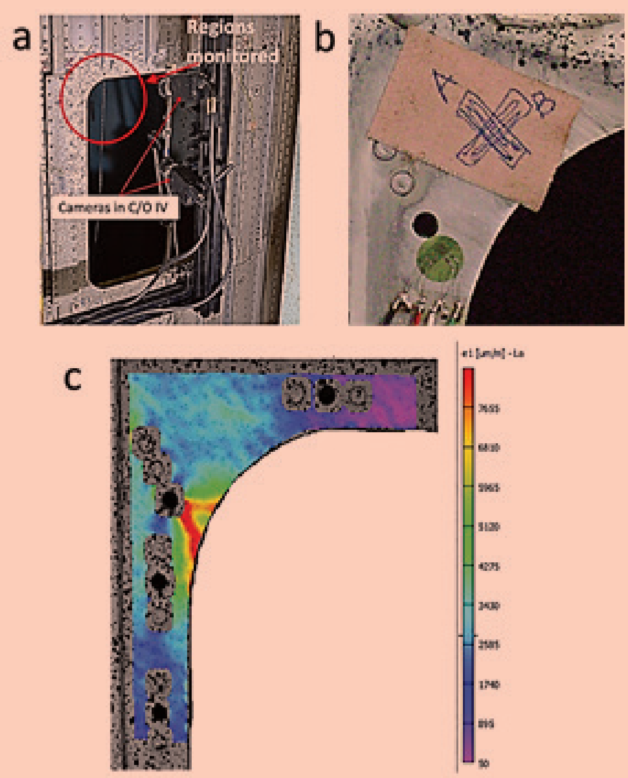
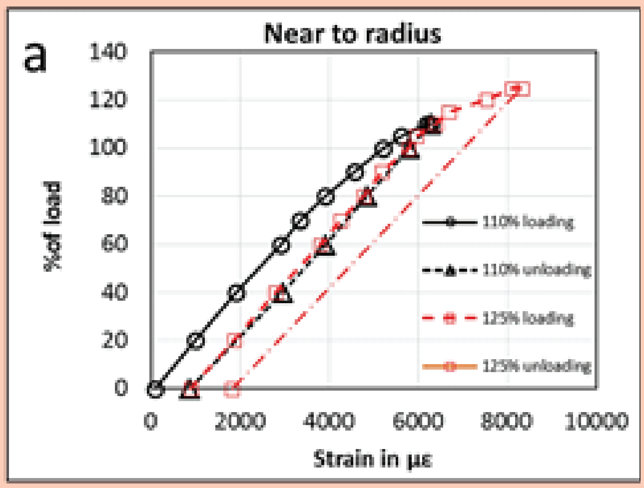


Figure 8.(a) Image of a cutout corner of an interstage structure with the DIC setup, (b) close-up view of the cutout and a nearby anchor nut hole, (c) full-field plot of the major principal strain are shown.

Anchor nut holes and rivets are used for assembling the cover-plates. The cutouts induce stress concentration hence they become vulnerable areas for yielding. Moreover, when anchor nut holes are created near the corners, the design becomes more critical at the cutout corner due to the interaction of the hole with the corner. This case is a planar interaction of the two stress concentrations unlike the previous case.

Figure 8(a) shows an image of the random patterns generated at one corner of a cut-out of an interstage structure. A close-up view of a nearby anchor nut hole is shown in Figure 8(b). The full-field strain plot at the maximum load is shown in Figure 8(c). Figure 8(c) shows the interaction of the corner with the anchor nut hole. The presence of the hole creates a delta kind of strain pattern where two weaker paths are created. The highest strain occurs near the hole which decreases towards the cutout. The variation of the principal strains at the hole edge and cut-out edges are shown in Figures 9(a) and 9(b), respectively. The interstage had undergone two cycles of loading namely, the proof load and the design ultimate load. The proof load is 1.1 times the design load and the ultimate load is 1.25 times the design load. In Figure 9, the strains in these two cycles are shown. It can be seen that during the proof loading the cutout and the corner had undergone similar levels of strain, however the hole edge had maximum residual strains.



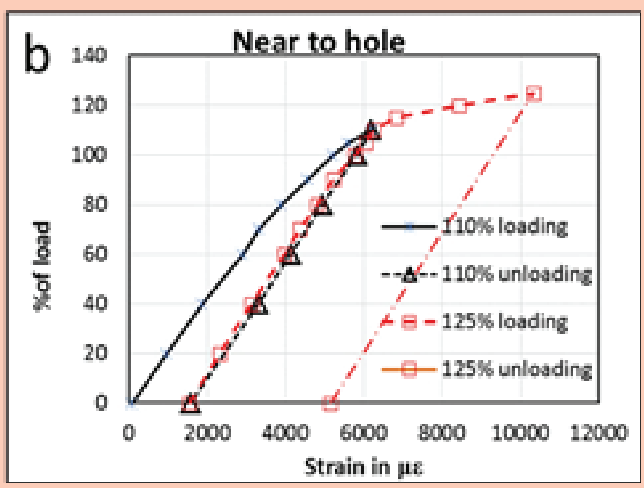


Figure 9.The variation of major principal strain at (a) the cutout corner and (b) at the hole edge; during loading and unloading of the structure.

It can be noted here that DIC cannot measure strains at exactly the hole edge for small size holes. Therefore, the strains measured near the hole edge would have been lesser than actual hole edge, which would have undergone higher strains. This might be the reason the point near the hole edge shows maximum residual strains. In the ultimate loading, however the strains at the hole edge was increasing rapidly than the cutout edge. The peak strain near the hole edge was around 0.0105. The residual was 0.0052. Similarly the peak strain at the cutout edge was 0.0082 with a residual of 0.002 unit strain. These observations show that the region near to the cutout should have yielded. This was not predicted through the FE analysis, as the effect of the anchor nut hole was neglected. Thereby, DIC inputs provided extra information about the structural response, which can be implemented to improve the designs.

CONCLUSION

The limitations of conventional strain measurement techniques could be overcome though DIC. LV designs being complex, minute detailing during FE analysis cannot be carried out as deviations during fabrication cannot be modeled. Therefore, it calls for improved measurement tools for obtaining the response of the structure at the weaker locations. The four case studies in this paper show variety of stress concentration that could occur in LV subassemblies. The strains measured through DIC in one case was found to be much smaller than the predicted values through FEA and in another case it was reverse. The uncertainties during the computational studies needs to be addressed. In these scenarios DIC can play a key role. Moreover, DIC would help in improving existing designs by finding the response at critical regions.

ACKNOWLEDGEMENTS

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MIRROR IMAGE

Image has been successfully brought out with the efforts of young team led by Shri. Girish N Namboodiri. I place on record the excellent work done. Now it is time for new office bearers and I hope the tradition of bringing out Image would continue with new vigor.

In the recent past one of the major flyover bridges had developed cracks and this has been investigated by experts. The cracks over girders and pier caps were caused primarily due to inadequate usage of cement and steel is one analysis. But one wonders how, efficient NDT would have helped. There are some basic methods that are used, as listed below, that enable examination of the integrity of concrete structures.

- Visual inspection.
- Half-cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete.
- Schmidt/rebound hammer test, used to evaluate the surface hardness of concrete.
- Carbonation depth measurement test, used to determine whether moisture has reached the depth of the reinforcing bars and hence corrosion may be occurring.
- Permeability test, used to measure the flow of water through the concrete.
- Penetration resistance or Windsor probe test, used to measure the surface hardness and hence the strength of the surface and near surface layers of the concrete.
- Cover meter testing, used to measure the distance of steel reinforcing bars beneath the surface of the concrete and also possibly to measure the diameter of the reinforcing bars.
- Radiographic testing used to detect voids in the concrete and the position of stressing ducts.
- Ultrasonic pulse velocity testing, mainly used to measure the sound velocity of the concrete and hence the compressive strength of the concrete.
- Sonic methods using an instrumented hammer providing both sonic echo and transmission methods.
- Tomography modeling which uses the data from ultrasonic transmission tests in two or more directions to detect voids in concrete.
- Impact echo testing, used to detect voids, delamination and other anomalies in concrete.
- Ground penetrating radar or impulse radar testing, used to detect the position of reinforcing bars or stressing ducts.
- Infrared thermography, used to detect voids, delamination and other anomalies in concrete and also detect water entry points in buildings.

Of the above, ultrasonic pulse velocity method as given by IS13331: 1992 part one, would enable to detect the presence of cracks, homogeneity of concrete and changes in quality of concrete with respect to the standard requirement. The principle behind the Ultrasonic Pulse Velocity is that the pulses are generated by an electro-acoustical transducer. When pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of different material phase within the concrete. A complex system of waves is developed which include longitudinal, shear and surface waves. The receiving transducer detects the onset of longitudinal waves which is the fastest. This is because the velocity of the pulses is independent of the geometry of the material through which they pass and depends only on its elastic properties. When quality of concrete in terms of density, homogeneity and uniformity is good, higher velocities are obtained. In case of poorer quality of concrete lower velocities are obtained.

Well as professional societies we need to make awareness and training programmes for such areas which affect the safety of day today constructions. It is our duty to provide the possible solutions also in improving the situation. Let me thank the readers of Image for encouraging me with their feedback on Image in general and this column in particular.

Mohan Ananthanarayanan

Editor, IMAGE

Image

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

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