

Stress Thermoelastic Forum Photonics

A Newsletter of Thermoelastic Technology

Vol.1, No.6, April 1995

First Words

There are a number of exciting news items to bring to your attention in this issue of the *Thermoelastic Forum*. First and foremost, Stress Photonics' new array based thermoelastic stress analysis camera is now being demonstrated and offered for sale. The *DELTA THERM 1000* is a high frame rate infrared camera integrated with special signal processing electronics to produce near-instantaneous thermoelastic stress images. The *DELTA THERM* system will be on display at the spring SEM conference in Grand Rapids, MI the week of June 12. Within the next few months, you will be receiving a brochure explaining the capabilities of the *DELTA THERM 1000*.

As many of you know, the *DELTA THERM* system was developed by Stress Photonics under SBIR funding from NASA-Langley's NDE Sciences Branch. NASA has joined "forces" with Wright Patterson's NASP Joint Program Office to fund continued development of the *DELTA THERM* system. The new Phase II SBIR contract includes the development of a number of key applications: elevated temperature, fracture mechanics, variable and impact loading, and composite damage assessment.

Stress Photonics is offering a spring course on Thermoelastic Stress Analysis (TSA) May 8-9. The "Tid Bits" column in this newsletter provides further details, as well as highlights from last fall's course.

Also in this edition of the *Thermoelastic Forum*, the "R&D Side" features an in-depth article on Stress Photonics' new *DELTA THERM 1000*, "Tech Tips" shows you how to eliminate the "Zig Zags" from your SPATE scans, and the "Events" column highlights last fall's SEM conference and notes other upcoming conferences.

The R&D Side

DELTA THERM 1000

By Jon R. Lesniak

Several years ago, Stress Photonics was awarded a phase I, and subsequently a phase II, SBIR contract from NASA-Langley to develop array-based Thermoelastic Stress Analysis (TSA) technology. Stress Photonics is pleased to introduce the fruits of this effort, the *DELTA THERM 1000*. This new technology has provided image acquisition times of approximately 10 seconds while minimizing the system's size, weight, and complexity. The short stress imaging time is accomplished through a combination of array detector technology and

high-speed digital processing. The system provides near-instantaneous stress images under most common structural loading.

The *DELTA THERM 1000* can display near-instantaneous stress images, near-instantaneous DC images, time-averaged stress images or time averaged DC images on a standard video monitor. Key images can be transferred to a lap-top control computer for storage and simple analysis. The images can be studied in depth at a workstation with *DELTA VISION* software. The rapid feedback associated with the system's "video camera-like" ease of

operation will drastically improve operator efficiency as well as minimize training time. The camera is focused by viewing the "live" DC image. The desired image area is determined while monitoring the near-instantaneous stress images. The final image is time-averaged and sent to the computer. There are no sensitivities to set and phase can be set automatically.

The near-instantaneous images immediately reflect set-up errors before testing time is lost. The DC images



The *DELTA THERM 1000* Stress Imaging System

provide excellent documentation of the test set-up as well as serving many other useful functions, such as thermal NDE methods or standard IR camera operations.

Designing and building a TSA system is quite a challenge; approximately 100,000 background photons are emitted for every signal photon created by the thermoelastic effect. Only the exquisite



See "DELTA THERM" page 3



Examining SPATE data are Lance Hartsig of Rockwell International, Scott Stevens & Colmen McDonough both of Pratt and Whitney West Palm Beach, & Dan Meissner of the University of Wisconsin.

Events

Fall SEM conference

"Integration of FEA and Structural Testing with Rapid Prototyping" was the title for last fall's SEM conference. Stress Photonics exhibited *DELTA THERM* images and *DELTA VISION* software.

To encourage more industry participation, papers were not required for presentations. There were, however, two presentations that dealt with thermoelasticity.

"Damage Tolerance Design Verification via Thermoelastic Stress Analysis" by J.R. Lesniak, Stress Photonics Inc., A. Nagar, Wright-Patterson AFB and B.R. Boyce, Stress Photonics Inc.

Lesniak presented a method of using Thermoelastic Stress Analysis to find the stress intensity factor, K_I . The technique can then be used to evaluate how critical a crack is.

"Rapid Stress Analysis with Rapid Prototyping" by N.F. Enke, Ford.

Enke's work involved using TSA on a Rapid-Prototyped dogbone specimen. This work is significant because a TSA design check of a Rapid-Prototyped component could

Upcoming AIAA conference

On April 10-14, 1995, The American Institute of Aeronautics and Astronautics (AIAA) will be having its 36th *Structures, Structural Dynamics, and Materials* Conference at the Sheraton New Orleans Hotel. Stress Photonics will be demonstrating the *DELTA THERM 1000* during a Technology Exhibit/Demonstration session. For more information contact AIAA, 370 L'Enfant Promenade, SW Washington, DC 20024-2518.

Thermosense XVII

(part of SPIE's AeroSense '95)

The International Society of Optical Engineering (SPIE) is holding its *Thermosense* conference April 17-21 at Marriott's Orlando World Resort and Convention Center in Orlando, FL.

At the conference, Lesniak will be presenting "*Differential Thermography Applied to Structural Integrity Assessment*" by Lesniak and Boyce for the Thermosense working group.

Forced-Diffusion Thermography (FDT) is a nondestructive evaluation technique that detects cracks and subsurface delaminations.

Tid Bits

Stress Photonics TSA Course

In October 1994, Stress Photonics hosted a course entitled "*Using Thermoelastic Stress Analysis Effectively*." The University of Wisconsin-Madison campus was the site for the course, which offered classroom lectures, as well as hands-on laboratory time.

The course was designed for both experienced and inexperienced SPATE* technicians and engineers. Attendees learned ways to improve SPATE data, such as using out-of-phase images to gage data quality. Advanced applications were also discussed, including fracture mechanics and high-temperature work.

Stress Photonics will host a spring TSA course at the same location May 8-9. This course will be geared towards SPATE users as well. For those new to TSA, an introductory course is in the works.

Those who took the course in the fall gave it rave reviews. Representatives from Pratt-Canada, Association of American Railroads, Bell Helicopter Textron, GM-Luxury Car, GM-North American Truck, Pratt-FL, Rockwell International and Ometron all attended. Bill Shust of AAR said, "It was the best course I've ever taken."

Come join us in Madison. We'll help you improve your SPATE'n skills, discuss your toughest SPATE problems, and have fun showing you "MadTown."

Contact Stress Photonics or send in the reader response card if you would like to attend, and we'll send you detailed course information.



Scott Stevens of Pratt & Whitney West Palm Beach sets up a SPATE scan.

*SPATE is a trademark of Ometron Inc.

From "DELTA THERM" page 1

sensitivity of modern detectors combined with sophisticated electronics and signal processing has made it possible to design imaging systems that provide a useful level of thermal, and hence, stress resolution.

The *DELTA THERM 1000* employs an InSb focal plane array (FPA), which has the best performance to cost ratio. The camera has 16,384 (128x128) detectors working in parallel to reduce noise by staring at their respective sample areas for the entire acquisition time, approximately 10 seconds. Special high-speed digital electronics were developed to process the incoming signals at frame rates up to 1000 frames/second assuring that the advantage of the multiplicity of detectors is not lost in a signal processing bottleneck.

The array camera correlates the IR signals digitally described by the relation

$$S = \frac{2}{N} \sum_{n=1}^N y_n \sin \beta(n) \quad (1)$$

where *S* is the amplitude of the signal, *y_n* is the sampled signal, *N* is the number of samples, and *sinβ(n)* is a reference.

To increase dynamic range, a high-speed offset technique is implemented where the offsets are calculated on a per detector basis and are updated continuously.

The noise of the end measurement *S* as described by Eq. 1 is related to the scan time by

$$\text{Noise} \propto \frac{1}{\sqrt{t}} \quad (2)$$

This means that the image quality improves with time as described in Fig. 1.

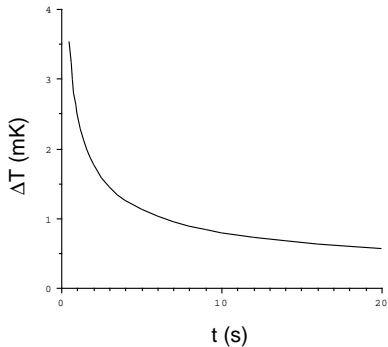


Fig. 1 Resolvable temp. vs time

The stress image is immediately apparent; the operator need only wait the short time necessary to obtain the level of quality

A common question about the use of an array camera is what effect does the detector to detector variance have on the stress image. Because the electronics system has a map of the detector sensitivities, the variance can be eliminated in the image processors. Detectors with substandard performance can be compensated for with values from the nearest neighbors.

The *DELTA THERM* system is very robust; it is solid-state requiring no optomechanical devices. The few optical elements required for a staring array make the best use of the available IR radiation and makes adapting the optics for special purposes easy. There already exists a wide variety of lenses for the *DELTA THERM* system.

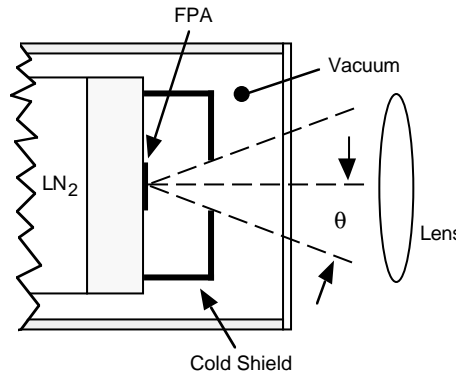


Fig. 2 *DELTA THERM* optics

DELTA THERM is already proving great usefulness for product testing, fracture mechanics and aging aircraft studies. Stress intensity measurements have been demonstrated at both room and high-temperature.

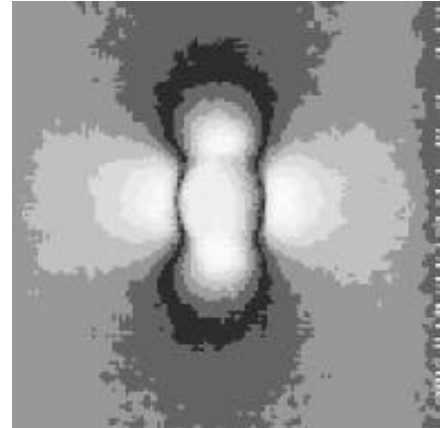


Fig. 3 *DELTA THERM* image of a hole in an aluminum plate

TSA will take a giant step forward as a result of this new array-detector technology becomes available. We think the capability to make near-instantaneous full-field stress maps efficiently will make TSA an essential engineering tool.

For more information about the *DELTA THERM 1000*, contact *Stress Photonics* or send in the reader response card.

Thermoelastic Forum is produced by
 Stress Photonics Inc. • 565 Science Drive • Madison, WI 53711
 (608) 233-2878 • FAX (608) 238-5120 • strphoto@vms2.macc.wisc.edu

Place Postage Here

565 Science Drive
Madison, WI 53711

From "Events" page 2

The DELTATHERM system is used for FDT much like it is used for TSA, but in FDT the cyclic temperature change is caused by a projected heat pattern instead of the thermoelastic effect.

Upcoming Spring SEM

The 1995 spring SEM conference, "1st International Conference on Mechanics of Time Dependent Materials," will be held at the Amway Grand Plaza Hotel in Grand Rapids, MI, June 12-15. As part of the Thermal Methods session, two papers of particular interest will be presented.

"The Use of Thermoelasticity in the Analysis of Fatigue Cracking in the Web Gap of Steel Bridges" by M.J. Fleming, University of Wisconsin-Madison and J.R. Lesniak, Stress Photonics Inc.

"Thermoelastic Analysis of Stress Concentrations in Thin Cylindrical Tubes" by J.M. Dulieu-Smith, P. Panutas, University of Liverpool, P. Stanley and C. Garroch, University of Manchester.

Don't miss the Thermal Methods Round Table jointly sponsored by the Thermal Methods division of SEM and the SPATE Applications Working Group (SAWG). Monday, 6/12, 8:30 - 9:50 a.m.

While you're at SEM, make sure to visit the Stress Photonics booth on the trade show floor to see the latest in Thermoelastic Stress Analysis.

Tech Tips

Unidirectional Scanning Eliminates the ZigZags

The latest release of the SPATE 9000 software has a new feature: unidirectional scanning. Unidirectional scanning eliminates the jaggedness of the vertical edges, common to most SPATE scans. The jagged appearance is caused by mirror motor hysteresis.

The SPATE software directs the mirror motor to a certain point. Because of the mirror motor hysteresis, the location of that point varies dependent on the previous location of the mirror. When a mirror originating on the left is commanded to go to the center, it settles slightly left of center. Conversely, if a mirror originating on the right is commanded to go to the center, then it settles slightly right of center. This phenomenon, coupled with the SPATE's default bidirectional horizontal raster pattern, results in vertical edges with a zigzag presentation.

The amount of mirror motor hysteresis often depends on the age of the equipment. The prominence of the jagged edges is a result of the size and fineness of your scan, whether or not you regularly smooth your scans and, of course, how much hysteresis your horizontal mirror motor has.

The most palatable solution to the problem is unidirectional scanning, that is, using a scanning raster pattern that always approaches from the same side. Ometron can upgrade your software to the latest version, which would allow you to collect all of your future scans with the unidirectional scan feature. The alternative is to replace the mirror motors. This solution is, however, quite expensive (approximately \$9200.00).

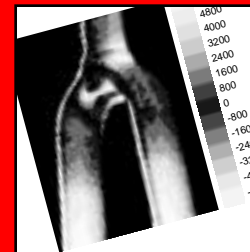
If you would like to eliminate the jagged edges from scans that you have already collected, we can help. Stress Photonics can write software that will offset every other row of a bidirectional scanned image by a specific number of DAC steps.

If any of these solutions sound appealing, call Stress Photonics and we will be happy to suggest how they might be done or implement them for you.

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 Send detailed information on the TSA course

Comments _____



Thermoelastic Stress Analysis (TSA) collects a full-field stress map by imaging temperature changes with a sensitive infrared camera. TSA is a non-contacting technique based on the thermoelastic effect. All materials, whether solid, liquid, or gas, change temperature when compressed or expanded.

A special infrared camera known as a differential thermographic system correlates the load-induced IR signals with the reference signal from the load system. This allows a thermal resolution of 1.0 mK which translates to the following stress resolutions (psi): steel - 150, aluminum - 60, and epoxy - 8.0.

Join us at our conference booth.

Stress Photonics

Stress Photonics Inc. • 666 Science Drive • Madison, WI 53711 • TEL: (608) 238-2878 • FAX: (608) 238-5120

Look for this ad in your SEM conference brochure.