

Stress Thermoelastic Forum Photonics

A Newsletter of Thermoelastic Technology

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First Words

Considering the length of time since our last issue, Stress Photonics has many new ideas, products, and events to relate to you. One item is a new level of cooperation between Stress Photonics and Ometron. SP and Ometron will have some joint product development efforts: Ometron will be selling SP products outside North America, and SP will assist with sales and service in North America.

In this issue: 1) Make sure you don't miss reading about three exciting new products: Data Maximizer Software, V-Amp and the SPATE 4000 camera head. 2) The Events column summarizes important technical papers presented at the June Society for Experimental Mechanics conference in Dearborn and the July conference on Aging Aircraft jointly sponsored by SEM and SPIE. 3) As always, Tech Tips provides a helpful little hint for your SPATE work. 4) For your more intellectual moments, the R&D Side provides the technical detail behind Stress Photonics' new V-Amp product. 5) Our new column, Tid Bits, describes a hint from a SPATE user. If you would like to contribute an article or even just a "tid bit," send it to the *Thermoelastic Forum* at Stress Photonics.

The R&D Side

Multiple Input Variable Amplitude TSA System

By Jon Lesniak

In many situations it would be extremely time efficient and informative to be able to perform TSA scans while a component is undergoing its routine road-load simulation or other multiaxial testing. In these situations, SPATE scanning via single-frequency correlation is inefficient because the load energy is distributed over a range of frequencies.

This article describes an extension to the single-input variable-amplitude approach developed by Stress Photonics under NASA funding. In that project, we showed that non-periodic signals can be analyzed with a simple digital-correlation algorithm. Essentially, the algorithm least square fits the SPATE signal to the sampled reference (fig. 1). Of course, the reference must be free of phase changes, DC offsets, and other distortions. A load cell signal usually provides an acceptable reference.

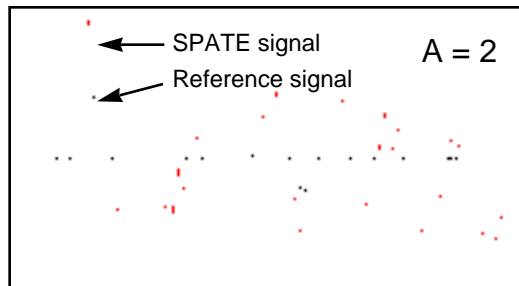


Fig. 1 Variable Amplitude Reference and SPATE Signal

For a multiple input system like the John Deere biaxial test fixture depicted in fig. 2, the stress at any given point will be a linear

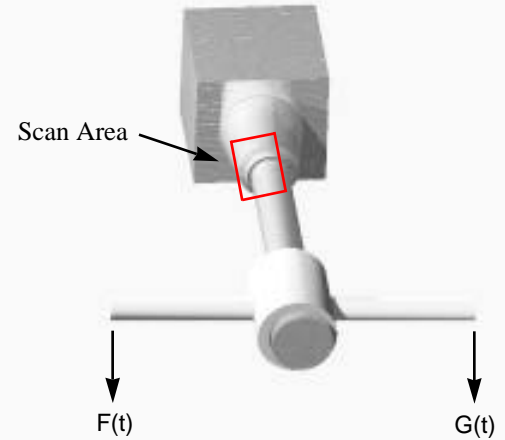


Fig. 2 Biaxial Test

combination of all load inputs described by a multiple regression equation of the form

$$\sigma(x,y,t) = A(x,y)F(t) + B(x,y)G(t)$$

where $F(t)$ and $G(t)$ are the time histories of the load inputs and $A(x,y)$ and $B(x,y)$ are the regression coefficients taking the form of distinct images. Each image describes the stress pattern influenced by each respective input.

By using the multiple regression equation the simultaneous stress images can be determined by the simple relation

$$A(x,y) = (K_4K_2 - K_5K_3)/K_6$$

$$B(x,y) = (K_1K_5 - K_3K_4)/K_6$$

where K_1, K_2 are the running sums

$$K_1 = \sum_{n=1}^N F_n^2 \quad K_2 = \sum_{n=1}^N G_n^2 \quad K_3 = \sum_{n=1}^N F_n G_n$$

$$K_4 = \sum_{n=1}^N S_n F_n \quad K_5 = \sum_{n=1}^N S_n G_n \quad K_6 = K_1 K_2 - K_3^2$$

See "V-Amp" on page 3

New Products

Ometron's SPATE 4000

Ometron's new SPATE 4000 was once again presented at this year's SEM conference. Last year, Ometron showed a prototype and collected enough constructive suggestions that it took until now to implement them all. The 4000's completely new scan head and new Windows software has several important improvements over the 9000. The new camera is easier to set up because of its clean rectangular shape. Inside, the mirror motors have been improved, optical paths further optimized, a laser integrated into the head to aid in aiming, and a DC thermal output provided. The 4000 head is interchangeable with the 9000 and makes a nice upgrade for an aging 9000 system. The 4000 software is built around a graphical user interface with a Windows pull down menu system. The operation of the lock-in has been computerized and made substantially easier. We feel this turnkey system is a good match when the SPATE system is used for fairly repetitive scanning, when it is used only occasionally, or when it is operated by a less experienced person.

Stress Photonics' V-Amp

Stress Photonics now offers an economical product that makes it possible to use SPATE when constant-amplitude loading is not available. Many labs perform variable-amplitude fatigue/durability testing and would like to be able to use their SPATE system to obtain stress patterns from these tests. Stress Photonics has designed V-Amp, a hardware/software package that makes it practical to use the SPATE 9000 to collect stress patterns from single and multiple input variable amplitude (V-Amp) tests. Sampling times are typically 0.1 to 0.5 points/sec for single input sys-

tems and twice that for dual input systems. The V-Amp system can measure stresses caused by loadings between 2 and 100 Hz. For more technical detail on V-Amp, refer to the R&D Side column. Prices vary throughout the world, so contact Stress Photonics or the nearest Ometron representative for pricing.

Stress Photonics' Data Maximizer Software

Now available in the U.S. are the Image Manipulator and Smart Smoother options of the Data Maximizer Software package for SPATE 9000. The Image Manipulator option removes spatial distortions and provides mirror image correction, image rotation, and subscan extraction. These features combine to make a powerful package that improves SPATE outputs. Image Manipulator orients the outputs to more natural or expected views and assists the comparison of SPATE data with other stress analysis techniques. As an added bonus, the Image Manipulator improves operation of the Scan Geometry and Screen Annotator portions of the SPATE 9000 software.

The Smart Smoother software uses Fourier transform techniques to identify and reduce noise from SPATE images. Optical, thermodynamic, and stress gradient criteria all indicate the maximum possible spatial gradient in a scan. Smart Smoother takes advantage of this information to remove gradients above the threshold of possibility. The main advantage of the Smart Smoother is that it eliminates the guess work from choosing the proper amount of smoothing and does not blur important detail.

You can get more information on the Data Maximizer software packages by contacting Stress Photonics, your nearest Ometron representative, or by sending in the reader response card.

Tech Tips

SPATE Software Focus Ring Calculation Parameter Modification

By Brad Boyce

Within the SPATE 9000 software there is a short routine that calculates the proper focus ring setting for the working distance entered by the user. When focus data is generated for a scan unit, a formula of the form

$$\text{RingSetting} = A(d-B)^C - D$$

(where d is the working distance) is fit to the data. The parameters A , B , C , and D are recorded and entered into the scan software for that particular head. If a new focus curve is run for a head or if a new head is matched up with a particular set of scan software, then the parameters A , B , C , and D need to be changed in the software.

To enter new parameters follow these steps:

1. Load your SPATE 9000 software system and start it.
2. Press the Stop key and issue the commands

```
LOAD "SPP"  
EDIT FOCUS_A
```

3. On your screen should be the explicit assignment of the parameters A , B , C , and D . Change them to the values listed on the recent metric focus curve.
4. We suggest that you enter a comment line near Focus_a that dates the entered parameters and indicates the serial number of the scan unit for which they are valid.
5. Make the changes permanent by saving the SPP program with the command

```
RE-STORE "SPP"
```

6. Now, to activate the modified SPATE 9000 software just type

```
RUN
```

If you have any difficulties or need help please feel free to call or fax Stress

"V-Amp" from page 1

A variable amplitude scan takes slightly more time than a normal SPATE scan, although not nearly as long as some earlier FFT techniques.

As with the single input case, the reference input must be free of phase changes, DC offsets and distortions. A load cell signal is

found to be adequate in most cases. In order to separate the influences of multiple inputs, the load shapes must be distinctly different.

Because heat transfer will attenuate DC and low frequency temperature changes, low frequencies are removed from both the reference and the SPATE signals by matched high pass filters set at a 1-5 Hz cutoff. Low pass filters are used (usually set at 100 Hz) to minimize high frequency noise.

The software allows the imaging to be based on any linear combination of the two load inputs. For example, in the case of John Deere biaxial tests, it is preferable to compile separate images representing the stresses due to bending and torsion. To do this, the software samples the load cell references and combines them to form the desired references.

$$R_1(t) = F(t) + G(t) \text{ (Bending)}$$

$$R_2(t) = F(t) - G(t) \text{ (Torsion)}$$

The running sums are calculated substituting R_1 for $F(t)$ and R_2 for $G(t)$.

Even if the images are collected using $F(t)$ and $G(t)$ directly, the torsion and bending images can be calculated through image addition and subtraction.

Indicators are used to assess the correlation between the fit and the SPATE signal, and the ability to separate between the two references. For example, the formula below determines whether the two inputs are sufficiently independent

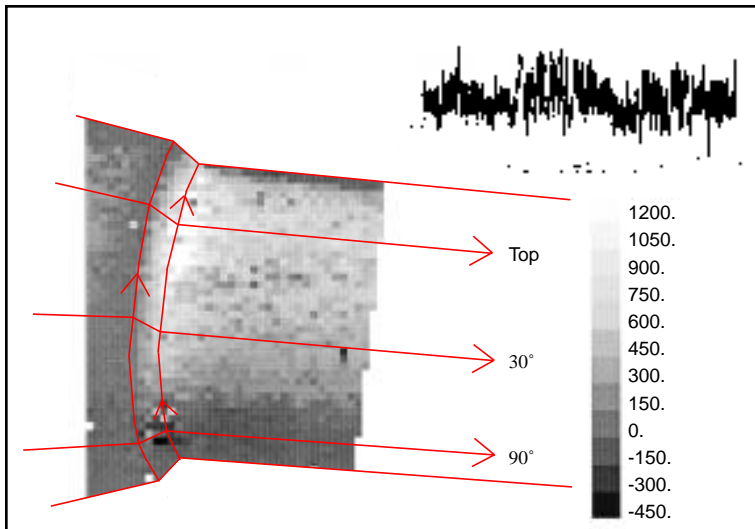


Fig. 3 Bending Image

$$\sqrt{\frac{K_3}{K_1 K_2}} = \begin{matrix} 0\text{-Distinct} \\ 1\text{-Similar} \end{matrix}$$

This definition is similar to the vectorial definition of cosine. Like the cosine function, a value of 1 implies the reference functions are similar, and a value of 0 implies that they are distinct. In the event of insufficient loading or inseparable references, the sample period is repeated.

Figure 3 is a TSA scan of a John Deere biaxial test specimen. This image

shows the stresses caused by bending. This sample was undergoing a fatigue test loaded with a SAE Log Skidder load history. The SPATE scan was collected without interfering with the test in progress.

We would like to thank Paul Swanson and the John Deere Technical Center for their cooperation in the collection of these early data sets.

Tid Bits

By Brad Boyce

Most SPATE operators find plotted focus curves difficult to read. Our experience is that mistakes are regularly made when reading these curves. One SPATE 8000 user found a solution to this problem. He fit a curve to his focus data, programmed the curve into an inexpensive hand-held calculator, and stuck the calculator to the side of the camera head. Now the operator can quickly enter the working distance and, voilà!, the correct focus ring setting appears.

If you want help fitting a curve to your focus data, contact Stress Photonics. We're happy to be of service.

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Events

Spring SEM Conference Highlights

By Brad Boyce

Nine papers of particular interest were presented this past June at the Spring SEM conference in Dearborn, Michigan.

"Infrared Staring Arrays and Digital Signal Processing" by Ryall and Wong

This paper may have raised the most interest at the conference. By using an array detector and digital signal processing, the Australian based Aeronautics Research Laboratory was able to make quality 486 x 510 TSA images in as little as 10 minutes. Predictions are that soon array detectors will collect images even faster.

"Thermoelastic Stress Analysis of Structures Under Random Loading" by Miles, Sandor, and Mahoney

"Thermoelastic Stress Measurements on a Bridge Loaded by Traffic" by Boyce, Zuraski, and Miles

Both papers deal with the same topic covered in this month's R & D Side.

"Quantifying Distributed Damage in Composites Under Random Loading Using Thermoelastic Stress Analysis" by Mahoney, Miles, and Sandor

"The Use of Thermoelasticity to Evaluate Stress Redistribution and Notch Sensitivity in Ceramic Matrix Composites" by Mackin

These two papers describe how TSA can be used to quantify and track damage in composites. The papers give some hope that in the future one may be able to assess the level of damage in a composite component or structure with TSA.

"Progress in Thermoelastic Evaluation of Mixed-mode Stress Intensity Factors" by Stanley and Dulieu-Smith

This paper explores the exciting capability of TSA to be used readily to make stress intensity factor measurements, a feature that, until now, has seen far too little attention.

"Thermoelastic Data Improvements" by Lesniak

As an extension of information presented in earlier R&D Side articles, this paper describes many techniques that are

now available in the Data Maximizer products by Stress Photonics.

"Recent Advances in Determining Individual Stresses from Thermoelastically Measured Isopachics", by Rauch and Rowlands

Rauch and Rowlands put forward a number of interesting ideas in this paper that have been evolving over several years of work.

Stress Photonics Presents New Technology at Aging Aircraft Convention

Stress Photonics has been exploring the idea of using differential thermography in non-destructive inspection applications. Jon Lesniak has developed the ideas for using differential thermography for NDE and presented them for comment at two NDE conferences. These ideas have received very favorable responses and work is now under way at Stress Photonics to develop this technology further. We refer to the new technology as Force Diffusion Thermography (FDT). Jon's most recent presentation of FDT was at a July aging aircraft NDE session jointly sponsored by SPIE and SEM.

FDT projects a dynamic pattern of heat onto the surface of the structure. The structure absorbs this energy and conducts heat from hot to cool regions. Flaws will impede the flow of heat, causing disturbances in the local thermal pattern. Patterns resembling moving parallel lines have been found to find cracks as well as disbonds and delaminations.

Dynamic patterns allow the use of the same differential IR cameras used for thermographic stress analysis, and the continuous illumination means low wattage projectors can be used in place of the high wattage flash lamps used by other thermal methods.

If you would like to learn more about FDT, watch for your next issue of the *Thermoelastic Forum* and/or use the reader response card to request **"Force Diffusion Thermography"** by Lesniak

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