Stress Photonics

Thermoelastic Forum

A Newsletter of Thermoelastic Technology

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First Words

We are excited about the excellent response that we have had to this newsletter. Many SPATE users have told us that they find the *Thermoelastic Forum* very useful. Whether good or bad, we like to receive your feed back. If you find an article in the newsletter that raises questions, give us a call. We are always happy to discuss your SPATE applications or questions.

Let us remind you that Stress Photonics would like this newsletter to be an open forum. If you have a topic you would like covered, or if you want to contribute a thought, suggestion, article, or even a complaint, we are all ears.

Need extra copies of this or either of the the two previous newsletters? We have an ample supply. Just mark the appropriate box on the reply card and we'll include them with your next mailing.

Many of us will be vacationing during the winter holidays so we would like to take this opportunity to wish you a safe, happy, and refreshing holiday season.

The R&D Side

Stress Intensity Measurement through Image Deconvolution

By Jon Lesniak

Stress Photonics is currently developing software aimed at helping the SPATE user more accurately and conveniently quantify stress intensity parameters. A key part of this software is improving edge data, where a majority of stress intensity measurements are made. In this article, I will show how optical blur can be corrected through a deconvolution of the SPATE image in order to achieve more accurate stress measurements.

Hole in Plate

Let's look at an example situation. Figure 1 shows the SPATE signal near a hole normalized to the nominal stress. The data was collected from a 4" wide plate with a 5/16" center hole. The scan was performed at a camera distance of 24". The theoretical stress concentration for this geometry is approximately 2.75, yet the data would suggest an intensity factor of 2.45. This represents an 11% error. Errors of 20% or more are common in this situation. These inaccuracies can be a critical impediment when making fatigue life predictions.

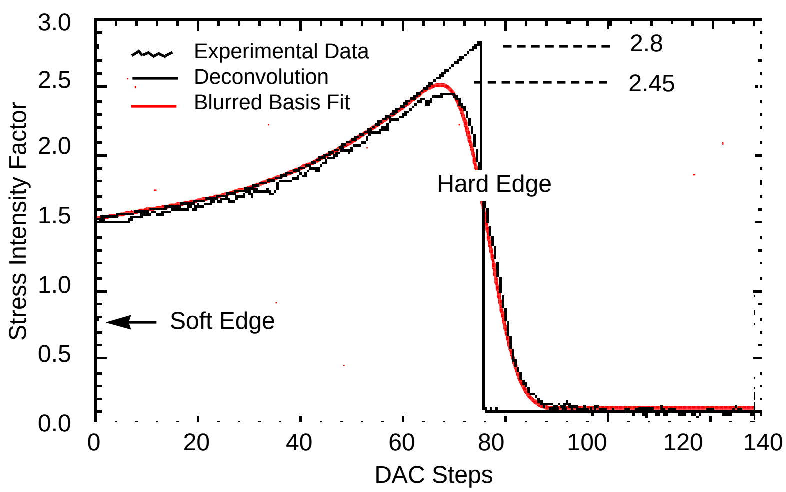

Fig. 1 Deconvolution

Deconvolution

The concept behind the deconvolution is that all the signal from the stress concentration is accounted for, but is spatially blurred. The detector spatial sensitivity profile can be measured to describe exactly how the signal is blurred and this information can be used to put the signal back where it belongs. Therefore, this technique is a deconvolution not an extrapolation. The detector sensitivity profile for this study was obtained by scanning across a slit placed in front of a chopped heat source.

The deconvolution is accomplish by first selecting a mathematical basis that can reliably describe typical stress states. For the 1-D work I chose a very general Chebyshev basis, the first few terms of which are:

$$T_0(x) = 1$$
$$T_1(x) = x$$
$$T_2(x) = 2x^2 - 1$$

The stress distribution is assumed to be a linear combination of these fundamental polynomials.

$$\sigma(x) = C_0T_0(x) + C_1T_1(x) + C_2T_2(x) + ...$$

See "Deconvolution" on page 2

"Deconvolution" from page 1

Of course SPATE doesn't see it this way, it measures a blur of the linear combination. To model this, each polynomial is blurred. The SPATE data S(x) is equivalently the linear combination of the blurred basis T'.

$$S(x) = C_0T'_0(x) + C_1T'_1(x) + C_2T'_2(x) + ...$$

For example, figure 2 shows the T_1 polynomial and the blurred base T'_1 which is obtained by convoluting T_1 with the detector sensitivity profile. If the blurred basis is fit to the SPATE data the magnitudes of C_n can be found. Using these coefficients, the first equation can be solved for the stress distribution and a stress intensity factor can be estimated.

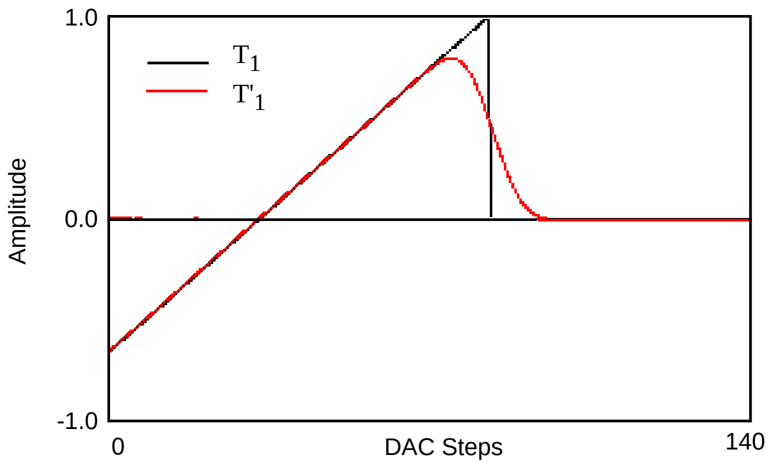

Fig. 2 Blurred Base Polynomial

Soft Edge

To make the application of this routine easier, two types of edges can be defined, a soft edge and a hard edge. A soft edge is defined as the edge of the data set that does not correspond to a geometrical edge. It is simply where the scan starts or stops in the middle of the stress field. The soft edge works best if set in a smooth stress field as demonstrated in figure 1. For the purpose of creating the blurred basis, the routine assumes that the base polynomial continues on past the soft edge (fig. 2.)

Hard Edge

A hard edge is set to correspond to a geometrical edge. In this case the basis is constructed to extend a detector radius beyond this edge in order to model the signal that is blurred over the edge. It is not always easy for the user to determine exactly where the geometrical edge is, so the software searches both sides of the user set hard edge to see if a better fit can be made with a refined edge position. The user only needs to get in the ball park.

Two Dimensional Deconvolution

In many cases a simple 1-D deconvolution will be adequate, but if the signal gradient is too severe normal to the scan line a 2-D convolution is necessary. Here the signal is described by a 2-D basis. The basis can be selected to impose compatibility requirements.

I am very interested in your stress intensity or other stress parameter needs. I would appreciate some feed back about your specific applications. Please give me a call.

New Products

Multi-Contour Software

By Brad Boyce

Stress Photonics has developed the *Multi-Contour Software* to meet the special needs of turbine blade SPATE stress analysis. The software is designed to aid in the location of high stress regions common to a number of vibrational modes of a single part. To use the software, several vibrational modes of a part are scanned. The scans are then smoothed and normalized to the highest stress within each scan. The index feature of the Filer is used to group the scans. The *Multi-Contour Software* is then used to overlay the highest contour lines from each frequency. By keying the color of the contours to the frequency of the scan, not the stress level as is normally done, a valuable plot is constructed for determining the strategic location of strain gages for subsequent testing.

Box Averager Software

By Brad Boyce

With the new *Box Averager Software* from Stress Photonics you can quickly find the average value of SPATE data within a rectangle drawn on the screen. The *Box Averager Software* is a handy little routine for calibration, damage assessment, or for finding nominal stress levels. The routine provides the capability to draw rectangular areas on the screen and can either find the average value within a rectangle or the average within a number of rectangles.

Both the *Multi-Contour* and *Box Averager Software* were written by Stress Photonics as the result of requests from users. If you would like to incorporate these routines or others of your own design into your SPATE or VPI system contact Stress Photonics.

Tech Tips

Color Hard Copy

By Brad Boyce

If you are interested in improving your color hard copy capability then you should learn about the HP DeskJet 550C. It's a low cost, high resolution printer. Part of the DeskJet line, it uses ink jet printing to produce laser printer quality outputs. It has a cut-sheet paper feed, parallel and serial ports, and conforms to Hewlett Packard's PCL (Printer Control Language) just like HP's LaserJet printers.

The Deskjet 550C offers an interesting combination of features:

- The printer is fairly low cost ($750)
- Black on white text is high quality and fast (3 page/min.)
- Color outputs are brilliant, and high resolution
- Paper handling is simple

The only drawback to the printer is that color outputs can take as much as five minutes per page.

To use the printer for SPATE applications you can use the HP PaintJet printer driver provided with your HP Basic computer. A simple modification to the driver (available free from Stress Photonics) is needed to take advantage of the resolution range of the DeskJet. The printer can either be connected directly to the HP computer's serial port, or the HPIB through an HPIB/parallel interface to speed printing. If you have a DOS computer or a Mac nearby it works great for them too! If you are considering a printer purchase give us a call, we'd be happy to discuss the options with you.

Disk Space

By Brad Boyce

Are you constantly out of disk space? Well, there are some inexpensive things you can do about it.

One of the things you can do to improve disk space is to use a utility program that HP provided you with your HP BASIC language. The "MASS_STOR" program can be used to repack a disk. Due to the way HP BASIC uses disk space (under the Logical Interchange Format, LIF) the disk tends to become fragmented. Small areas of unused disk space pile up as files are added and deleted from your drive. Repacking the disk recovers this unused area. How much area you can recover using "MASS_STOR" depends on how you use your system. A recovery of 10-20% of the space on your disk may be possible.

If you still don't have enough space you should look into buying some more disk space. Although new HP equipment can be expensive, Stress Photonics has found that used HP equipment is inexpensive and reliable. Generally, 10Meg will go a long way to solving your space problems. We recently priced a used 20Meg drive at $550 with overnight delivery. Give us a call if you need the names of some sources of used HP computer equipment.

Events

June 7, Detroit Spring SEM Conference

The next SPATE Application Working Group Meeting will be held in Detroit in conjunction with the SEM Spring Conference. Mark your calendars for Monday 7 June 1993. Two technical paper sessions, a thermoelastic tutorial, and the SAWG meeting/round-table discussion will all be held that day. And of course there will be the manufacturers exhibits as well. The conference will be held at the Hyatt Regency, Dearborn, Michigan.

Publications:

"Thermoelastic Determination of Individual Stress Components in Loaded Composites," Feng, Z., Zhang, D., Rowlands, R.E., Sandor, B.I., Experimental Mechanics, June 1992.

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Individual Stress Component Separation of Thermoelastically Measured Isopachic Stresses

By B.J. Rauch & R.E. Rowlands
Department of Engineering Mechanics, University of Wisconsin-Madison

Excerpts from a paper to be presented at the Spring 1993 SEM conference, Dearborn, Michigan.

This paper describes a finite element based scheme which accurately and efficiently separates the isopachic data into the individual in-plane stress components. The governing elliptic partial differential equations require complete boundary conditions to be well-posed, however, it is shown that the stress separation algorithm can be employed with incomplete boundary conditions and yield accurate results. Examples with theoretical and experimentally measured isopachic data are given to demonstrate the technique.

Complete boundary conditions are not always available for a problem. This paper demonstrates the amount and type of information that is necessary for an engineering quality solution. Particular attention is given to the use of additional information that can be obtained by natural boundary conditions or additional experimentation, such as strain rosettes.

Figure 1 and 2 are the separated normal stresses in the horizontal and vertical directions respectively for a plate with a central hole. The specimen was loaded in the vertical direction by both a force and a small moment. The isopachic stresses were experimentally measured and further processed with smoothing and edge enhancement algorithms before stress separation was performed. The correlation with strain gage measurements was excellent.

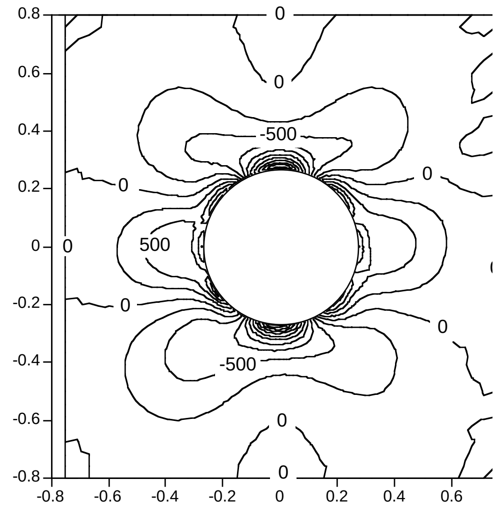

Fig. 1

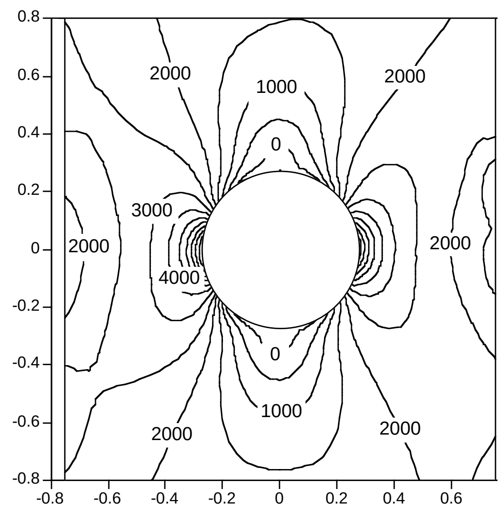

Fig. 2

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