Session 3659

Laser Induced Fluorescence Imaging Of Thermal Damage in Polymer Composites Using LabView and IMAQ Vision

Asad Yousuf, P.E
Professor, Electronics Engineering Technology
Savannah State University

ABSTRACT

Polymer-composites (PMC's) are becoming increasingly important in the production of high performance vehicles and aircraft, where their low weight and high mechanical strength, combined with advancements in manufacturing technology, ensure increased use for a variety of applications. Of particular concern in the aerospace industry is the tendency of some PMC materials to become irreversibly damaged when exposed to elevated temperatures. This paper will discuss fluorescence based imaging system capable of identifying regions of thermal damage in polymer-matrix composites.

In an effort to further understand the intervening functions assigned to the assessment of thermal damages in polymer composites this paper will demonstrate a PC-based virtual instrumentation system using the Image Acquisition (IMAQ) Vision software with the General Purpose Interface Bus (GPIB) controlled by the LabView (Laboratory Virtual Instrument Engineering Workbench) software.

I. INTRODUCTION

Spectral imaging is the determination of spatially distributed and chemically/biologically distinct elements in heterogeneous material. It is a powerful tool for studying a wide range of materials including biological materials, polymers, and semiconductors. Advances in the field of spectral imaging made through the development of a number of different types of technology, including digital image processing hardware and software, and continuously tunable, image quality spectral filters have resulted in the rapid collection of specific images that have high contrast and high resolution.

Typical non-destructive techniques are capable of detecting flaws, such as cracks and delaminations, but cannot detect initial heat damage, which occurs on a molecular scale. There are many methods in use such as: Thermogravimetric Analysis (TGA), Scanning Electron Microscopy (SEM), Optical Microscopy and etc. used to investigate heat damage of composites and epoxies. Spectroscopic techniques such as Laser-Induced
Fluorescence (LIF) can detect molecular changes of the polymer matrix resin that results from elevated temperatures. LIF can be used as a tool for quantifying and imaging heat-

induced damage in PMC panels [2]. LIF possess the capability to determine the basic relationship between heat-induced damage, excitation wavelength, fluorescence intensity, and fluorescence wavelength. This technique can be used for lightweight and field portable inspection devices for rapid, in service, nondestructive detection of heat damage in polymer matrix composites.

This paper begins with a discussion of the approach used in the prototype system and is followed by a discussion on the imaging system. The block diagrams representing the program written in LabView are presented. Finally to provide a broader understanding of image acquisition, the paper concludes with a discussion on future work relating to the plug-in image acquisition board, and image processing capabilities of IMAQ vision software.

II. APPROACH

(Fisher et., al., 1996) conducted a study on thermal damage of polymer matrix composites. In their study two-dimensional fluorescence intensity imaging of heat induced damage was achieved using flood illumination of the sample as illustrated in Figure 1.0. Results of their study indicate that at a fixed emission wavelength, the maximum intensity will correspond to lightly damaged material. However Fisher et. al suggested that their results could only provide qualitative information about the severity of thermally induced damage.

It was strongly recommended by Fisher et. al, that in order to quantify damage estimates it is necessary to measure the wavelength of maximum fluorescence intensity. They suggested that the combination of fluorescence could be performed simultaneously using a wavelength-tunable imaging system, as illustrated in figure 2.0. An Acousto-Optic Tunable Filter (ATOF) could be used in front of the camera to select various fluorescence bands. A series of images, each corresponding to a different fluorescence emission wavelength band, could be acquired by simply tuning the filter, the sequence being repeated until all of the bands of interest have been acquired and stored.

In order to implement the system recommended by Fisher et., al. a prototype system was developed with LabView and IMAQ Vision software to provide a flexible and user-friendly environment for the analysis of thermal damages in PMC's.

III. IMAGING SYSTEM

The imaging system consists of a low-power solid-state diode laser to excite the source and an AOTF with appropriate optics, placed in front of a CCD camera to select various fluorescence bands. Hewlett Packard (HP) 8647A-signal generator was used to provide the frequency input to the AOTF to determine the wavelength. Virtual Instrument (VI) was developed to interface the HP8647A via the GPIB to a personal computer. This interface enabled the operator to change the RF from the front panel of the VI.
The ATOF is the major part of the imaging system, which provides the spectrum of wavelengths for the analysis of thermal damage in polymer matrix composites. An ATOF acts as an electronically tunable spectral band pass filter. It consists of a crystal in which acoustic waves at radio frequencies are used to separate a single wavelength of light from a broadband or multi-

source. The wavelength of interest identified for the application under discussion was 500 - 700nm. The wavelength of the specific light source that is diffracted is determined by the following phase matching condition:

$$\lambda = \Delta n \, \alpha \, va/fa \qquad (1)$$

The ATOF parameters referenced in Eq. (1) are defined below:

λ = Wavelength
Δn = Refractive index
va = Velocity of the acoustic wave
fa = Frequency of the acoustic wave
α = Geometry of Crystal

The process of image acquisition at different frequencies is controlled by the LabView. Initially the frequency is set from the front panel and the user can click on run camera from the front panel to acquire an image at this frequency and save the image in TIFF format. This process is repeated until images of all the bands of interest have been acquired and stored. The images are viewed in the LabView environment by using the IMAQ software.

IV. BLOCK DIAGRAMS

LabView is a development environment based on the graphical programming language G. LabView relies on graphical symbols rather than procedural language to describe programming actions. All LabView programs, or virtual instruments (VIs), have a front panel and a block diagram. The front panel is the graphical interface of the LabView VI. This interface collects user input and displays program output. The block diagram contains the graphical source code of the VI. The block diagram can include functions and structures from the built-in LabView VI libraries. This section will discuss the block diagrams of the VIs used in the system.

VI was developed to interface the HP8647A (signal generator) via the GPIB to a laptop computer. GPIB interface for PCMCIA is shown in figure 3.0. This interface allows the user to change the RF from the front panel of the VI. The main VI is divided into the following three parts:

1. Loop and Sub VI (HP 8647A)
2. Run Camera
3. Load Image

<u>Loop and Sub VI (HP 8647A)</u>

The wiring diagram for the VI is shown in figure 4.0. The outer loop is a For loop, this loop is executed 8 times (0-7). Inside the For loop is a While loop, the While loop has an iteration terminal i that counts the number of times the loop will execute. The condition terminal expects a true or false input. A true input forces the While loop to run indefinitely, and a false input terminates execution. The output of the iteration from the adder is connected to the sub VI (HP 8647A) shown in figure 4.0. The steps of execution are as follows:
When i = 0 then the frequency displayed on the signal generator is 80MHz (the user can always change this initial input frequency from the front panel). When the user clicks the next button i

=1 then (20*i + 80 = 100) the displayed frequency is 100 MHz and finally when I = 7 then (20*7 + 80 = 220) the displayed frequency is 220 MHz.

Run Camera

The wiring diagram for the VI is shown in figure 4.0. The command to be executed is inserted as a string inside the While loop. The command to be executed is hard wired to the EXEC sub VI; this VI is located in the communication section of the control panel. When the user clicks on Run Camera, the LabView passes the executable command to the System EXEC VI to run the camera software.

Load Image

There are two ways in LabView to display an image file, both of them however require Vision Toolkit for LabView. One way is to use the IMAQ Open file VI, then use the convert image to obtain an array. The output of the array VI can be wired to a LabView intensity graph and the image can be viewed in the graph (this will only look good if the image is 8-bit gray scale, color images will look bad since the intensity graph has only 8-bit resolution). A better way is to use the IMAQ Open File VI and wire directly to the IMAQ Windraw VI, this configuration will make the image appear in the floating IMAQ vision window.

V. FUTURE WORK

To develop a robust system for the assessment of thermal damages in polymer composites it is suggested that the system should include the necessary image acquisition components (hardware, driver software and the application software) for rapid prototyping and image processing capabilities. This section will provide a brief discussion on the necessary image acquisition components.

Image Acquisition Components

The essential components that make up an image acquisition solution are the plug-in image acquisition board, driver software, and application software.

Plug-in Image Acquisition Board

In order to develop a comprehensive and easy to use system to provide solutions for complex image capture for the analysis of thermal damages in PMC’s, the board chosen is PCI-1424 from National Instruments.

The IMAQ PCI-1424 is ideal for the acquisition of color and gray scale images. The PCI-1424 is also designed to control digital cameras. The advantage of the digital camera over the analog camera is that the signal is digitized at the CCD (charge-coupled devices) rather than at the image acquisition board, signal to noise ratio is typically higher, resulting in better accuracy. In addition the digital cameras now come with 10 to 16 bit gray levels of resolution. This higher resolution is required in the imaging applications.

Driver Software

NI-IMAQ driver software comes with the National Instruments IMAQ plug-in board. NI-IMAQ consists of extensive library functions that the user can call from the application programming environment. These functions include routines for image acquisition, memory buffer allocation, trigger control, and board configuration. The driver software performs all functions required to acquire and save images.

Application Software

The National Instruments IMAQ vision software, contains more than 400 image acquisition, analysis, and archiving functions integrated into LabView and LabWindows for development of powerful image acquisition solutions. IMAQ Vision image processing functions can be used to filter, manipulate, smooth, and quantify images. Arithmetic operations include add, subtract, multiply and divide. Also there are logical operations, NOT, AND, OR, XOR and compare. The IMAQ Vision software can provide the ideal software environment for rapid development of user friendly program to assess thermal damages in polymer composites.

VI. Summary

This paper presented a brief discussion of fluorescence based imaging system capable of identifying regions of thermal damages in polymer-matrix composites. A simplified prototype model that simulated the imaging system in LabView environment was presented. In addition to develop a robust system for the detection of thermal damages in polymer-matrix composites, the necessary image acquisition components were explored.

This research has served as a reference for providing students in engineering technology at Savannah State University with challenging and exciting experiences in modern computer-based instrumentation and control technology. These experiences will increase the students' ability to use PC-based instrumentation techniques while investigating classical engineering concepts.

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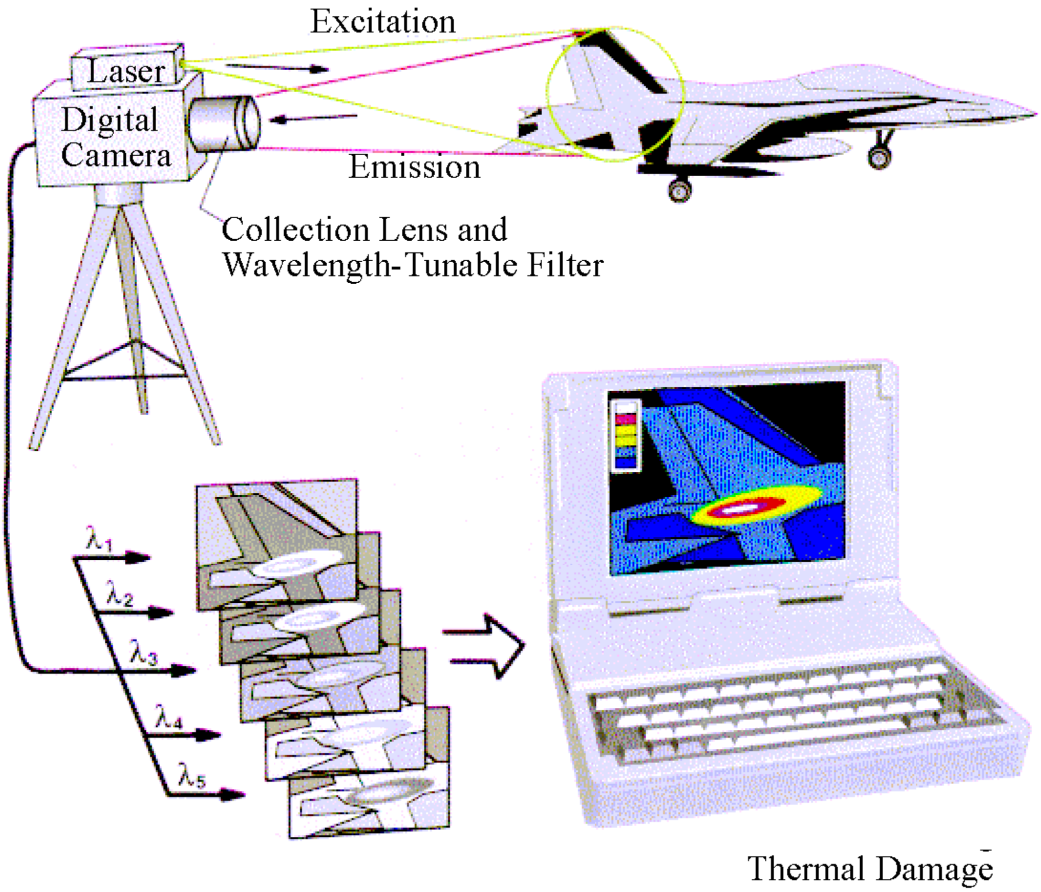


Figure 2.0. Illustration of design for a portable imaging system capable of providing quantitative damage measurement of fluorescence wavelength shift

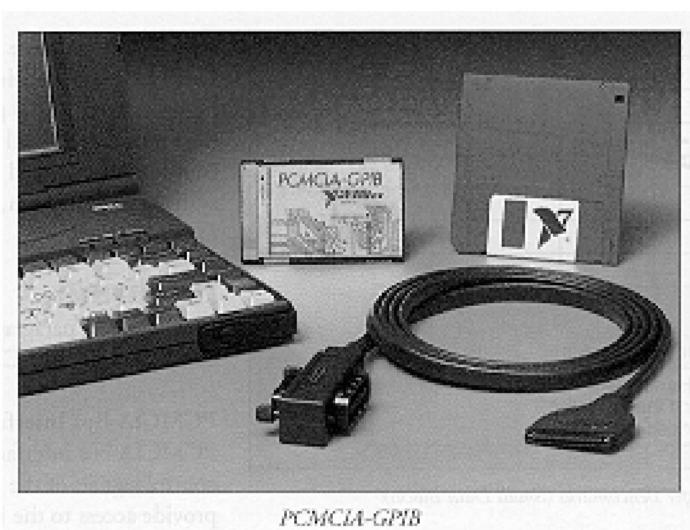


Figure 3.0. GPIB interface for the PCMCIA

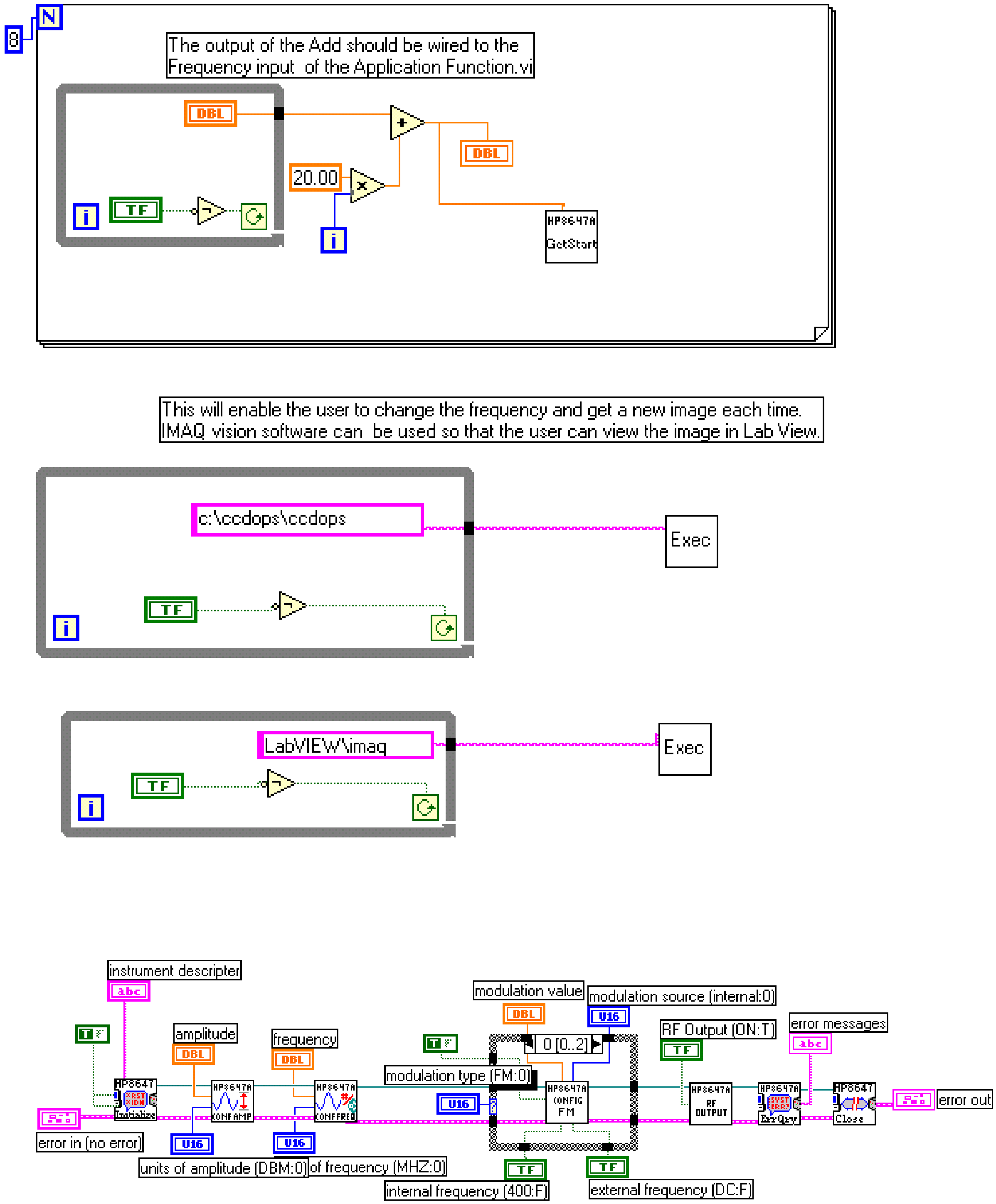
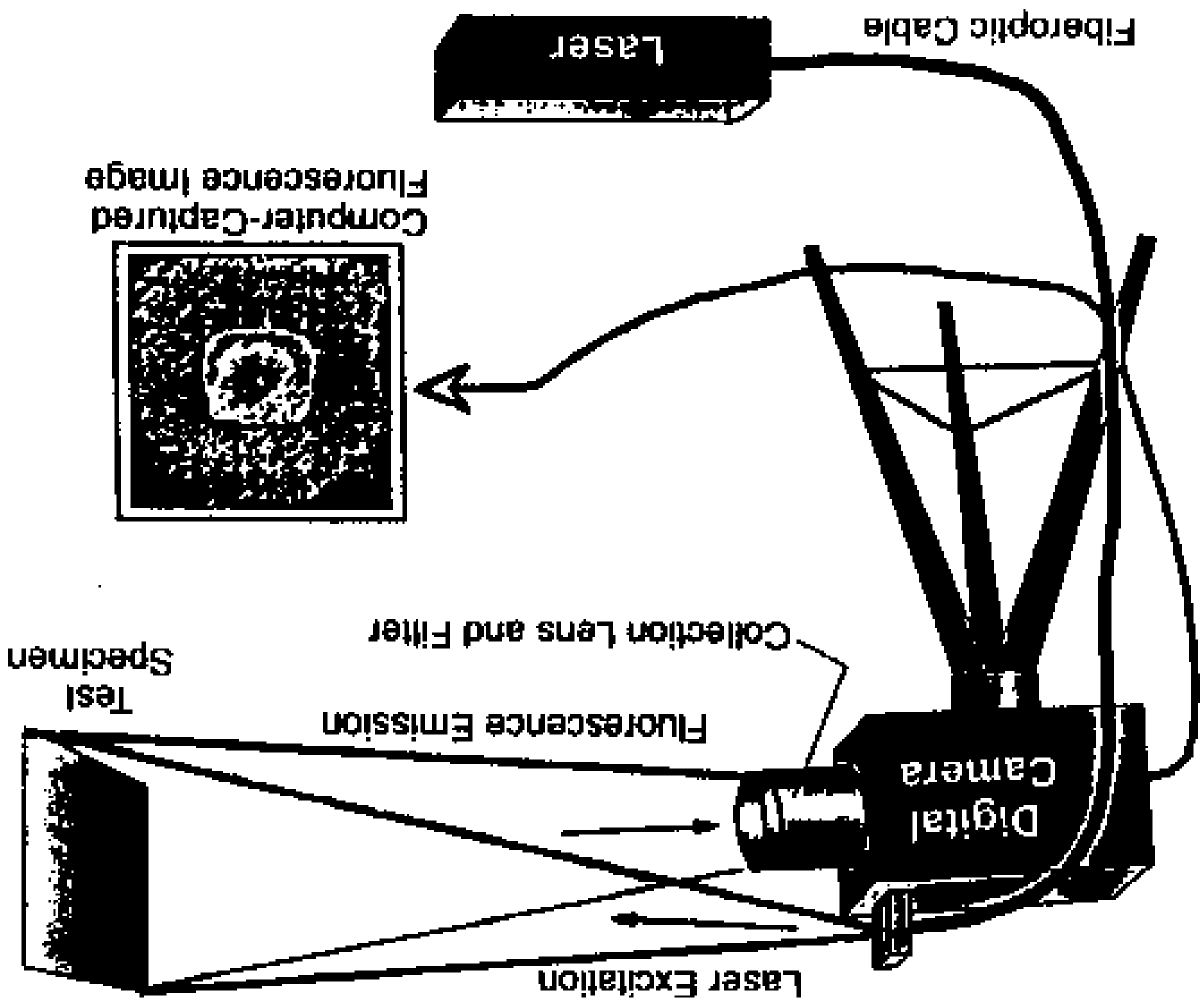


Figure 4.0. Block diagram of the imaging system and the sub VI HP 8647A



Fisher et al. Figure 1.0

ASAD YOUSUF

Asad Yousuf is a Professor of Electronics Engineering Technology at Savannah State University. He received his BS in Electrical Engineering from the NED Engineering University, Karachi, Pakistan and MS in Electrical Engineering from the University of Cincinnati. Asad is a registered Professional Engineering in Georgia and is actively involved in joint research with the defense industry.