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Remote, Simple Nondestructive Testing Of Composite Defects With An Ultrasound Camera: A Boeing Study

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Abstract

Imperium and Boeing have successfully demonstrated the ability to remotely control the Acoustocam with a wireless network and view its display screen in real time. The purpose of the demonstration was to show the capability of utilizing the device by a non-specialized user while being monitored by a nondestructive testing expert off-site. The demonstration was performed with the Acoustocam in a hangar environment and monitored in real time at an off-site facility.

Since there is a shortage of trained nondestructive inspection (NDI) specialists in the field, this could potentially address the concern of composite airframe operators for a quick simple method to detect internal damage. For example, if there were a need to inspect the composite structure at an airport terminal, a line mechanic could perform the inspection while guided by the expert in real time who may be thousands of miles away. The quantitative decision making necessary is performed by the remote expert.

Introduction

The device is a field portable, simple handheld ultrasound imaging camera, requiring one day of training. The user is not necessarily a trained nondestructive inspection (NDI) technician. The device is meant as a first line of defense to finding internal composite damage in aircraft structures. We have been teamed with Bell Helicopter and Boeing on much of this work.

The system is essentially a camcorder for ultrasound. The quality of the information imparted by this real time video image is far superior to that of conventional A-scan amplitude data or phased array ultrasonics. The images are easier to read and have much greater spatial resolution. Integration of ultrasound energy over the time period of a video frame results in high signal to noise and sensitivity. This in turn allows reducing the device to a simple, portable, low cost tool that any inspector can use.

Industry Needs

Advanced composite materials being used on newer platforms such as the V-22 and Joint Strike Fighter are obviously subjected to harsh conditions. The most prevalent scenario involves the material being impacted during the course of normal use. However, there is no reliable, simple device for large area composite inspection. This damage can often not be seen at all from the surface, making visual detection nearly impossible. This damage can have catastrophic results if not found before flight.

Currently, the technique of choice is tap testing or visual inspection. If nondestructive testing (NDT) tools are used, the most common is a standard UT probe providing pulse echo ultrasonic waveform data. The returning echo from the original ultrasonic pulse is digitized and processed electronically to provide information regarding the composite. Potential problems with the structure are identified with loss of back-wall echo and can be further characterized by reviewing the entire ultrasonic waveform data. This inspection is performed several times at the factory and during in-service usage.

The Acoustocam system is particularly suitable to address these needs; specifically the system has the following features:

- Can be used by non-specialist,
- Quick simple alternative to tap testing
- Designed specifically for the evaluation of hidden structures and materials,
- Proven in its capability to detect materials defects, composite delaminations, thermal and mechanical damage,
- Small, light weight, and low power,
- Designed for real-time in-situ NDE,
- Low cost,
- Can work on flat or curved parts,
- No disassembly or time consuming setup needed,
- Provides real time, simple feedback,
- Requires no extensive training
- Robust design capable of surviving hostile aerospace environments.

The subsurface imagery generated by the C-scan ultrasound laboratory system is striking for its video appearance. The imagery appears qualitatively similar to that obtained with visible light cameras. The camera head is connected to a base control unit which contains electronics and a single board computer (SBC) to control the camera and chip. The control unit is controlled by a graphical user interface with a touchscreen. A typical system is shown in Figure 1.

Figure 1. Ultrasound Camera System

To operate, the user places the probe against the target. A small amount of ultrasound gel is placed on the area to be imaged to allow the ultrasound to propagate from the probe into the target and begins imaging immediately. An image capture button on the camera probe would store up to hundreds of images before a download would be required. One future consideration is to put a wireless transmitter in the control unit so that images could be sent to a base station or another user in real time. The software on the touch screen which controls the camera and displays video is shown below. The interface shows both the C-scan and the A-scan. It shows the C-scan on the left with a crosshairs. The right side shows a full waveform which is the A-scan at the C-scan crosshairs. The A-scan has full flaw detector capabilities (material velocities, gates, alarms, etc.).

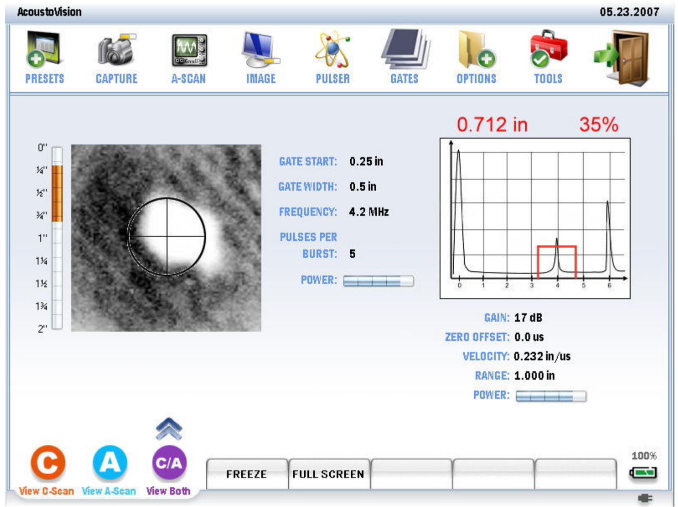

Figure 2: Graphical User Interface

Results

Imperium and several industry partners have investigated the use of the ultrasound technology for composite damage. For a period of three months, the system was evaluated for the inspection of barely visible impact damage (BVID) for Boeing. Dr. Gary Georgeson of Boeing provided samples for the study. The ultrasound camera was reviewed for both detection capability as well as ease of use.

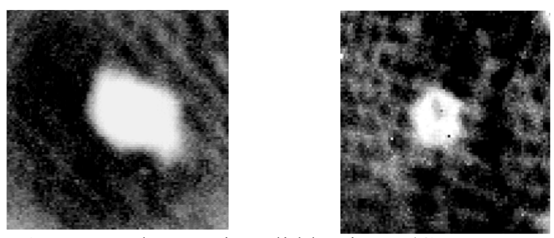
Figure 3: Impact damage in solid laminate (Courtesy: Boeing)

Since porosity is difficult to simulate, the system was evaluated with a real life example resulting from positive air pressure under the bag during cure of a production part. A sample image of the porosity is show in Figure 4. The porous areas are clearly visible.

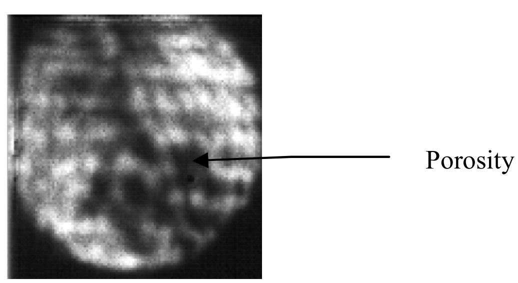

Figure 4: Image of Porosity (courtesy: Boeing)

Dr. Richard Bossi of Boeing writes that the ultrasound camera:

> *"…has the characteristics necessary to be successful…",* and *"…In particular it has been shown to be very easy to use and fast…".*

Based on these results, Boeing has endorsed this program. Mr Gary Georgeson of Boeing has expressed the following support:

"I now believe your device offers the potential for a non-specialized inspector to quickly and easily find defects with minimal training.."

-Gary Georgeson
Boeing Phantom Works
Seattle, WA

Boeing Wireless NDI Program

The quality of these results has led to a program funded by Boeing to transition the camera to airport loading gates for quick inspection of composites on commercial aircraft, for internal defect detection by a non-specialized technician. The images are monitored in real time via a local wireless network by an expert often thousands of miles away. The project, which has been developed in collaboration with Boeing engineers, will allow maintenance personnel to use Imperium's device to quickly survey damage without having to bring in harder to set up, conventional ultrasound equipment - all from remote locations.

The Acoustocam is a hand-held device that may be used as part of quick survey of suspected damage areas. The device shows subsurface defects that cannot be seen visually. The user simply places a probe against the aircraft structure and with proper equipment setup; subsurface defects appear on a handheld monitor in real time.

Ongoing Development Work

As part of several ongoing programs, Imperium is continually investing in new embodiments of the ultrasound camera. One program is to miniaturize our pulse echo handheld unit by a factor of two. Figure 5 below shows the smaller handheld now being tested. We are partnered with both Boeing and Bell helicopter on this program. Note a removable front end nozzle which contains a disposable neoprene balloon which can be easily replaced if the balloon tears.

a) Probe b) with front end removed

Figure5: Handheld probe

We are also developing a field portable through transmission system, shown in figure 6 below. The system is ideal for finding skin to core disbonds in honeycomb composites. The user simply places the unit against the target, such as a helicopter rotor blade, and 'paints' the area to be inspected. On the screen, a large area mosaic C-scan is created in real time.

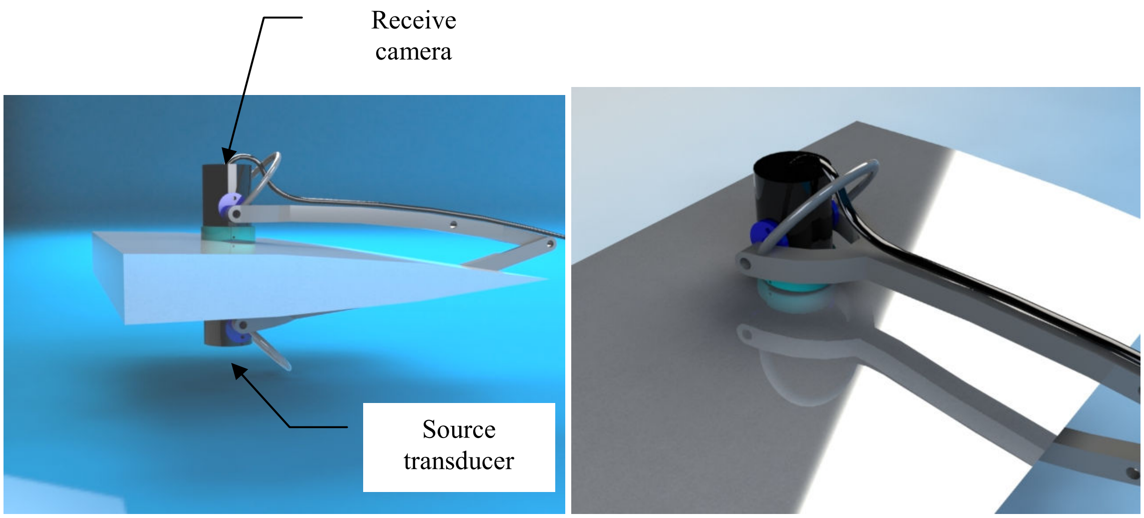

Figure 6: Through transmission configuration for skin to core disbond inspection

This type of system was used to immediately detect skin to core disbonds in a nomex core honeycomb structure. Figure 7 shows two images taken, one with a defect and one without.

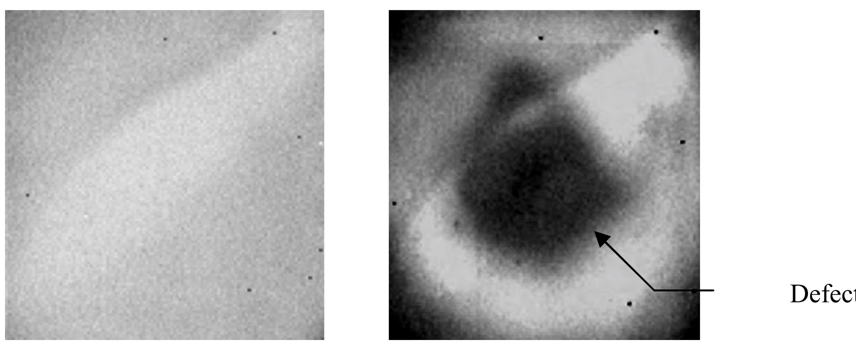

Figure 7: Aluminum core without, with ¼" skin to core disbond

Acknowledgments

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About Imperium, Inc.

Imperium, Inc. has been developing and manufacturing advanced ultrasound imaging systems since 1996. The company was founded by Dr. Marvin E. Lasser, the Chief Scientist of the US Army and former Director of Research for Ford (Philco Division). Current users of our products include companies such as Boeing, Airbus, Bell Helicopter, US Army, US Navy, US Air Force, US Army, and NASA. Applications of the technology can be found in industrial, medical, subsea, and biometric settings. The technology is protected by several granted and pending patents.