ACOUSTORAPHY
Acousto-Optical (AO) Ultrasonics &
Its Applications

International Workshop on Imaging NDE
April 2007
IGCAR, kalpakkam, India

Dr D S Dulay

NDT Consultants Limited
Middlemarch House,
Siskin Drive, Coventry, England, UK
CV3 4FJ

www.ndt-consultants.co.uk
NDT CONSULTANTS LIMITED

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LOOKING TO THE FUTURE
- Established 1985
- NDT Consultancy
- NDT Training (esp. Aerospace)
- NDT Specialist Services
- Research & Development
- Sales of High-Tech NDT Equipment
Level III Consultancy and Training

Aerospace & General Training & Qualification Levels 1, 2 & 3

Retained by Many Clients as Level III

Approved by: Rolls Royce, Boeing Int., Honeywell, Messier-Dowty

Consultancy for new applications, NDT Technique Development & Approval
NDT Consultants has R & D capability in following areas:

- **Systems Integration.**
  Automated NDT, Multi parameter and multi technology NDT, real time systems.
- **Software Development.**
  GUI, Wireless Communication, Data processing and data mining, defect sizing and characterization.
- **Electronics Instrumentation Development.**
  Embedded hardware, embedded software, VLSI, VHDL, Smart Sensors.
- **NDT Transducer Design and Modeling of behavior.**
  EMAT, Eddy Current, Ultrasonic.
Research & Development

EU, DTI and Privately Funded Research

Composite Inspection with Resonant Techniques
Phased Array EMAT for High Temperatures
Digital Radiography
Phased Array Ultrasonic's
Heat Exchanger Tube Inspection
Mechanics Free Wireless 3-D Scanning System

FreeScan Basic Concept

With no scanning arms, cables, rods or bulky transmitters connected to the probe it is very simple to use and is very user friendly in set-up.
FreeScan enables users to make a freehand scan with almost any type of sensor connected to an instrument which provides an Analogue (or suitable digital) output of the to-be-measured feature.

With no scanning arms, cables, rods or bulky transducers connected to the probe it is very simple to use and is very user-friendly in set-up.
N-BUS & FREESCAN for Composite Inspection

N-BUS applies Narrow Band Resonant Impedance Analysis where application specific resonant frequency has been determined and optimised by modelling.

The application field for narrow Band Ultrasonic Spectroscopy (or N-BUS) will increase rapidly with the growing application of layered structures in modern aircraft, for example, GLARE, FRP, CFRP and HONEYCOMB for aircraft such as the Boeing 787, Airbus A-380, Joint Strike Fighter F-35 etc.
MODELLING CAPABILITY
ACOUSTOGRAPHY?
NDT Ultrasonic imaging system of notable interest out side the traditional A-Scan, B-Scan, and C Scan etc.

**Acoustic Microscopy:**
Scanning Laser Acoustic Microscopy,
C-Mode scanning Acoustography,
Scanning Acoustic Microscopy,

**Acoustical Holographic Microscopy.**
Is the extension of Holography into the ultrasonic domain?
Two type of systems:
A) The liquid-surface Type,
B) The scanning Type
What is Acoustography?

Vibro-Acoustography?
Ultrasonic Acoustography?

Vibro-Acoustography.

Used in breast imaging, including detection of micro-calcifications, detection of arterial calcifications, and soft tissue imaging.

Based on Low-Frequency vibrations induced in the object using two intersecting continuous wave (CW). The two-ultrasound focused beams of different frequencies are aligned to intersect at their focal region.
What is Acoustography?

Acoustography is the Ultrasound analog of:

• Radiography
• Photography

Motivation

Make Ultrasonic Testing:

• Simple
• Fast
• Economical
Basic Principle – AO Sensor

- Acousto-optic sensor contains a layer of proprietary LC material
- LC molecules reorient when exposed to ultrasound
- Ultrasonically exposed area becomes birefringent showing contrast change
Basic Principle – Image Formation

- Full-field area imaging analogous to x-ray imaging
- AO Sensor similar to x-ray detector converts ultrasound into visual image
- Resolution controlled by ultrasound wavelength \( L \sim d^2/\lambda \)
Basic Principle – Image Formation

- Analogous to photography or video imaging
- Only a small portion of the specimen is imaged
- Stand-off distance needed
- Resolution diffraction limited (Rayleigh Criterion: limit of res. $1.22\lambda/2.NA$; $NA \sim D/F$)
Potential Advantages

- **FULL FIELD**: Area Inspection not point-by-point inspection
- **NEAR REAL-TIME**: Rapid screening of components
- **HIGH LATERAL RESOLUTION**: Ultrasound converted into visual image by minute molecules
- **SIMPLE**: Visual Image is intuitive, easy to interpret compared with electronic signals
- **LOW-COST**: lower skill operator need, which results in significant running cost savings
NDT System Development

Two general concepts are being developed:

• Through Transmission Mode UT
• Single-Sided (Reflection Mode) UT
Through Transmission Mode UT

Basic Concept
Through Transmission Mode UT

NDT System Configuration

Dedicated NDT System

Portable NDT System
### NDT Applications

Through Transmission Mode UT

**Composite Standard (Inclusions)**

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Through Transmission UT
10mm Thick Panel

Conventional C-scan
5 MHz

Acoustography
3.3 MHz
Through Transmission UT
40mm Thick Panel

Conventional C-scan
5 MHz

Acoustography
3.3 MHz
NDT Applications
Through Transmission Mode UT

Composite Panel (Impact Damage)

Conventional C-scan

Acoustography
NDT Applications
Through Transmission Mode UT

Tight Radii Inspection
NDT Applications
Through Transmission Mode UT

Tight Radii Inspection

5.7”

Side B

1.9”

Side A

Radius

5.7”
NDT Applications
Through Transmission Mode UT

Inspection of Attachments

Composite Plate with Vertical Attachment
Single Sided (Reflection Mode) UT

Basic Concept

System Prototype
NDT Applications
Single Sided (Reflection Mode) UT

Insonifying Beam
AO Sensor
Acoustic Coupling Layer
Test Specimen

NO DEFECT
DEFECT

REFLECTION MODE ACOUSTOGRAPHY
NDT Applications
Single Sided (Reflection Mode) UT

Plastic Test Panel Inspection

Test Panel

Preliminary Acoustography Results
NDT Applications
Single Sided (Reflection Mode) UT
Plastic Test Panel Inspection

Test Panel
Preliminary Acoustography Results
NDT Applications
Single Sided (Reflection Mode) UT

Composite Test Panel

Composite Panel
With Impact Damage

Acoustography Image
Making Sound Visible

NDT Applications
Single Sided (Reflection Mode) UT

Aluminum/Core Disbond

Acoustography image of Disbond
Single Sided (Reflection Mode) Acoustography based UT

Aluminum/Core Disbond

Disbond at skin/core Interface for 1mm skin
Skin/Core interface for 2mm skin
Transducer Field Visualization

ProbeScope PS 200
Transducer Field Mapping System
Transducer Field Visualization

5MHz, 1” diameter, disk-type unfocused transducer at various distances from the radiating surface: (a) 1.65cm; (b) 3.0cm; (c) 6.75cm; and (d) 10.5cm.
Field Visualization – High Frequency Transducer

40 MHz transducer (supplied by Dr. KK Shung)
Focal zone and beam spreading away from the focal zone.
Recent Developments

- Large Area Inspection
- Reflection Mode Inspection
- Flexible Sensors
Large Area Inspection – Composite Panel with inclusions

6"x3.5" Field-of-View
Large Area Inspection – Impact Damaged Composite

6”x3.5” Field-of-View
Large Area Inspection – Composite with Inclusions

6”x6” Field-of-View
GR/E Composite Plate Inspection-Impact Damage

Reflection C-Scan

Acousto-Optical Image
Conventional UT

- Contour-Following Needed
- Complex Mechanical Scanning Equipment Needed
- Equipment is Expensive
- HIGH Operator skill needed
AO Patch UT (The Vision)

- NO Contour-Following Needed
- NO Complex Mechanical Scanning Equipment Needed
- Equipment is NOT Expensive
- LOW Operator skill needed

Flexible AO sensor
Flexible Piezoelectric layer
Making Sound Visible

AO Patch UT (with Flexible AO sensor only)

- Flexible AO sensor
- AO sensor has memory capability
- Image retained after ultrasound exposure with transducer
AO Patch UT (Preliminary Results)

- Curved plexiglas specimen with blind hole
- Image produced with the flexible AO sensor is visible to the naked eye
- Image retained but can be erased with electric field.
AO Patch UT
(Preliminary Results)

- Honeycomb composite specimen
- Honeycomb structure visible to naked eye
- Image retained but can be erased with electric field.
Future Developments

• Increase field of view (e.g. 12”x 12”)

• Refine Single Sided (Reflection Mode) UT

• Develop acoustic coupling for non-immersion UT

• Develop Flexible AO Sensors
Summary

• Acoustography could be a simple alternative to conventional point-by-point UT

• It can be used for Thru-Transmission UT

• It can be used for Single Sided (Reflection Mode) UT
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