



Proceedings of Workshop



## Non-Destructive Evaluation Methods for Inspecting Offshore Composite Components



November 21, 2002  
Houston, Texas

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Shearography	Thomas Crump
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### **Working Groups Reports**

#### *Designing/Building Inspectability into Composite Products*

Chair: Bill Cole and Alex Selvarathinam

#### *Passive/Active In Situ Monitoring - Underwater/Downhole*

Chair: James Skogsberg and C. P. Hsiao

#### *Reliability of Inspection Methods and Candidates NDE Methods for Specific Applications*

Chair: Mamdouh Salama and Thomas Crump

### **Recommendations and Path Forward** Ozden Ochoa and Jerry G. Williams

# Non-Destructive Evaluation Methods for Inspecting Offshore Composite Components

## Executive Summary

**Jerry G. Williams, Petroleum Composites  
Ozden Ochoa, Texas A&M University – OTRC**

### **INTRODUCTION**

The advantages of using light-weight, corrosion resistant composite materials and structures for deepwater developments have become increasingly important in recent years and many composite components are being used or developed for use in the exploration and production of oil and gas. Early composite applications have been lightly-loaded, i.e., pipes and gratings which are primarily constructed of glass fiber and epoxy resin. Most qualification and in-service re-qualification to date have been based on test data and visual inspection. Advanced composite applications are now emerging for critical, primary structural components, such as drilling and production risers, drill pipe, spoolable high-pressure pipe, subsea pipelines, tendons, and synthetic fiber mooring ropes. These components are much more highly-loaded and therefore structurally demanding, and their remoteness from the surface introduces inspection and monitoring challenges. Alternative carbon, polyester, and other fibers as well as advanced resins are being proposed for applications. One of the main issues which has been identified as a technology deficiency inhibiting the deployment of composite components offshore is the effect of damage to components and the associated issue of how to find and determine the extent of damage. At issue is "Are there reliable, affordable Non Destructive Evaluation (NDE) methods which could be used to ascertain the fitness for service of components following manufacture and during service?" Reliable NDE methods that can economically monitor the performance and continuing integrity of composite component in critical structural applications could provide better understanding and confidence and lead to the development of rationale and realistic inspection strategies.

Composite manufacturing defects such as delamination and voids as well as damage experienced in service can lead to premature failure of the component. It is important that Non-Destructive Examination (NDE) methods be available to examine composite structure components to determine their state of fitness-for-service following manufacture as well as at scheduled and special times during the service life. Some of the NDE methods used for metals such as x-ray are also applicable to composites, but for the most part a completely different set of NDE tools must be used. There has been considerable research in recent years to develop NDE methods for the inspection of composite aerospace and automotive components. With a small amount of adaptation, some of these methods can be

applied to composite structures used offshore. Methods such as ultrasonic, radiography, thermography and acoustic emission are well established, but require skilled technician interpretation. Other promising methods such as fiber optic sensors, trip metal strain sensors and embedded sensors are just emerging. In addition, considerable research results are emerging from NDE applications in other industries. Interferometry methods such as shearography are being used to inspect large aerospace structures and may have merit for oil industry components. The lack of familiarity with the unique problems and challenges of the oil industry by NDE experts and similar unfamiliarity by the oil industry of the advancements that have been made in NDE technology currently inhibit the utilization of NDE methods.

The primary barriers to applying NDE technology in the oil industry are thus both technical and inadequate communications including: (1) lack of opportunity to develop experience-base inspection strategies based on actual in-situ performance of these new components, (2) need for advancements in applying NDE methods to the specific needs of the oil industry and (3) lack of information to assess the potential benefits, costs and limitations in applying NDE methods. The workshop on "Non-Destructive Evaluation Methods for Inspecting Offshore Composite Components" sponsored by the Texas A&M University Offshore Technology Research Center and the Minerals Management Service held on November 21, 2002 was designed to address these issues. The long-term benefit is expected to be to sort out what is needed, what is available, what can be developed, and to serve as a catalyst for development efforts to make available the technology to inspect composite components used in the offshore oil industry. The availability of reliable NDE inspection methods is important not only to the operators, but also for regulatory authorities to gain the both experience and confidence in the safe application of critical composite components being introduced offshore.

## **WORKSHOP OVERVIEW**

The workshop began with presentations by experienced authorities on currently available NDE technologies and newly emerging techniques. Stephen G. LaRiviere (Boeing Commercial Aircraft) gave a general overview of established NDE technology including: eddy current; radiography; linear diode arrays; storage phosphor detectors; flat panel digital radiography detectors; liquid crystal; electronic, pulsed, and ultrasonic thermography; shearography; pulse echo and through transmission ultrasonics; resonant transducer and velocimetric bondtestors; and automated tap testors. Jeff Muhs (Oak Ridge National Laboratory) discussed fiber optic strain gages, C. P. Hsiao (ChevronTexaco) described TRIP metal strain sensors, Tom Crump (Level III) highlighted shearography technology and Amrita Kumar (Acellent Technologies, Inc.) described the use of embedded sensors.

Tommy Laurendine (Chief, MMS Office of Structural and Technical Support) provided a summary of the Gulf of Mexico development activity and provided insight into MMS considerations regarding inspection of critical components used offshore. Talks were then presented on inspection strategies and NDE

technology under consideration for specific applications including: (1) risers, Kap Parfrey (ABB Vetco Gray); (2) risers and tendons, Mamdouh Salama (ConocoPhillips Inc.); (3) mooring ropes, Jeff Muhs (Oak Ridge National Laboratory); and (4) pipes and tanks, Tom Crump (Level III Inc.). Tom Crump also gave a brief report on a recent workshop sponsored by the Department of Energy, Office of Industrial Technology held November 13-14, 2002 in which NDE was a topic of discussion. Stephen G. LaRiviere gave a presentation on the NDE technology used by Boeing to inspect commercial aircraft composite components. The primary methods used include: visual, radiography, thermography, ultrasonic and eddy current.

The overheads used by presenters in their presentations are contained herein as listed in the Table of Contents.

For the remainder of the day, attendees were divided into three working groups to address the following topics:

- 1. *Designing/Building Inspectability into Composite Products***  
Chair: Bill Cole and Alex Selvarathinam
- 2. *Passive/Active In Situ Monitoring - Underwater/Downhole***  
Chair: James Skogsberg and C. P. Hsiao
- 3. *Reliability of Inspection Methods and Candidates NDE Methods for Specific Applications***  
Chair: Mamdouh Salama and Thomas Crump

As a guideline, it was suggested the working groups consider the following issues:

**1. *Designing/Building Inspectability into Composite Products***

Suggested Discussion Topics:

1. Methods currently used by manufacturers to inspect composites during manufacture and service.
2. How can design detail be used to enhance inspectability?
3. Practicality of sensors integrated into laminate: fiber optics / TRIP Steel / embedded sensors/other.
4. Guidelines on using NDE results in "fitness for service" assessments.
5. Recommendations for NDE advancements and implementation.
6. Level of inspection considered necessary by operators/regulatory?
7. Other relevant issues.

**2. *Passive/Active In Situ Monitoring - Underwater/Downhole***

Suggested Discussion Topics:

1. Define in situ inspection relative to offshore composite applications.
2. Methods applicable to in situ monitoring.
3. Logistics of in situ monitoring. ROV, data collection/interpretation.

4. Components that would benefit from in situ inspection.
5. Recommendations to resolve issues and stimulate solutions?
6. Level of inspection considered necessary by operators/regulatory?
7. Other relevant issues.

### **3. *Reliability of Inspection Methods and Candidates NDE Methods for Specific Applications***

#### Suggested Discussion Topics:

1. Categorize level of inspection needed for specific applications.
2. List candidate NDE methods for specific composite applications.
3. Categorize NDE methods relative to readiness for immediate implementation versus others needing refinement into practice.
4. How reliable are specific NDE methods applied to specific applications?
5. Recommendations for NDE technology transfer and development.
6. Level of inspection considered necessary by operators/regulatory?
7. Other relevant issues.

## **WORKSHOP GROUP REPORTS**

A summary of the oral reports provided by the three working groups is provided below.

### **1. Designing/Building Inspectability into Composite Products**

- A. The group focused primarily on tubular applications such as the riser with consideration of joints and liners.
- B. The group expressed concern that the industry not be burdened with excessive use of complicated NDE sensors making their application impractical.
- C. There was concern that Trip metal sensors could not create a large enough magnetic field to be easily measured.
- D. It was believed it would be practical to inspect a riser liner by pigging.
- E. A need was expressed for the establishment of criteria for critical damage.
- F. One suggestion was to use a visual witness layer to detect damage and wear.
- G. Long term aging degradation measurements can be performed in the laboratory and guidelines developed for design. It was pointed out that one can design for aging, but not inspect for it.
- H. Guidelines for composite products include equivalency with steel counterparts. It was proposed to determine through tests the correlation between damage & visual observation.
- I. It was highlighted that inspection of the metal to composite joint should be considered in the design. For example, a witness coating could be applied which would provide visual enhancement.
- J. Leading candidates for inspection of tendons was considered to be visual, fiber optics and measure of displacement in potted fittings.

## **2. Passive/Active In Situ Monitoring - Underwater/Downhole**

This working group took the approach of defining the gaps that inhibit the use of NDE technology to inspect selected composite components.

- A. Inspection Definitions
  - a. In place
  - b. In service
  - c. Can't retrieve for on-shore inspection
  - d. Expect component to be in water for its lifetime
  - e. Simultaneous field application
  - f. Data Retrievable
  
- B. Issues to resolve
  - a. Connectivity
  - b. Attachment to the structure
  - c. Data transmission and retrieval
  - d. Power
  - e. Data interpretation
  - f. Acceptance criteria / FFS
  - g. Long-term reliability (redundancy)
  - h. Environmental impact (sea water exposure, etc.)
  - i. Temperature limitations
  - j. Marine growth
  - k. Commercial / cost
  - l. Trained personnel
  - m. Psychological resistance.
  - n. Field trials
  - o. Industry standards, practices, procedures.
  
- C. Components:
  - a. Drilling and production riser + choke & kill lines. ●
  - b. Polyester mooring ropes ●
  - c. Air cans
  - d. Flowlines and manifolds
  - e. Heave plates in truss spar
  - f. Spoolable pipe ●
  - g. Tendons (Carbon fiber) ●
  - h. Choke & kill lines.
  - i. Riser towers
  - j. Casing & production tubing

Note ● - for working group results, see table below.

D. Gaps Analysis: The results of the gaps analysis are presented in the following table. The numbers tabulate the votes of nine participants in the group who ranked the readiness of NDE technology for application for five components including: production riser, polyester mooring rope, spoolable pipe, and carbon tendons. The definitions for technology readiness are:

P - Project ready within 1 year.

D - Development project taking 2-3 years.

R - Research required to make ready in 3-5 years.

Component	Technology Readiness	Production Riser	Polyester Mooring Rope	Spoolable Pipe	Carbon Tendon
Visual	P	2	9	9	
	D	6	0	0	
	R	0	0	0	
Fiber Optics	P	0	0	0	0
	D	7	9	9	9
	R	0	0	0	0
TRIP Metal	P	0	0	0	0
	D	9	4	3	8
	R	0	5	6	0
Acoustic Emission	P	1			
	D	1			
	R	7			
Ultrasonic External	P	0		0	
	D	4		3	
	R	3		4	
Ultrasonic Embedded	P	2		0	
	D	6		3	
	R	1		6	
Thermography (Water Ingress)	P	0		1	
	D	2		0	
	R	6		8	
MEMS	P	0	0	0	0
	D	2	0	0	0
	R	7	9	9	9
CT	P			0	
	D			0	
	R			9	
Removable Insert	P		9		
	D		0		
	R		0		
Displacement of Potted Termination	P				9
	D				0
	R				0



- E. How to resolve issues and fill the gaps.
  - a. NDE efforts should be in parallel with design efforts
  - b. Need an overall strategy supported by the industry
    - Risk Assessment
    - Economics
    - Fill the gaps.
  
- F. Priority for projects and funding
  - a. JIP
  - b. University study
  - c. DOE/MMS
  - d. Field Trials
  - e. Industry Standard Practices
  
- G. Level of Inspection Considered Necessary by Operators/Regulatory
  - a. Need Risk Assessment. Risk = POF x consequences
  - b. Need Inspection Interval
  - c. Failure Modes
  - d. Acceptance Criteria
  - e. Failure scenario
  - f. Industry standards, practices
  - g. Effectiveness of inspection
  - h. Inspection/NDE methods
  - i. Determine when no inspection is needed.
  
- H. Other Issues
  - a. Downhole condition monitoring
  - b. Ship hull
  - c. Umbilicals

### **3. Reliability of Inspection Methods and Candidates NDE Methods for Specific Applications**

This group primarily concentrated on discussion of NDE issues associated with risers and tethers. It was indicated the industry policy is not to repair damage critical components, but to remove them.

#### **Tendons:**

- Use 3-D X-ray during manufacturing
- The potted termination is main issue. The method proposed is to monitor the displacement of the potted termination within the socket.
- Some testing is required to determine critical damage size. Fatigue for carbon tendons not considered a critical issue.

### **Risers:**

- Need to define critical modes of failure / flaw size.
- Opportunity to inspect: Fabrication and in service.
- Porosity need – ultrasonic not structural performance
- Failure modes – fiber breakage. Transient thermal inspection infrared.
- Compton backscatter – single side inspection from backside – not turn key . low gamma energy. Would require ROV.
- Recommended investigate use of low gamma energy Compton backscatter to inspect during service life.
- Consider thermography: use heated water under pressure or heat impulse on the OD to give latent image. Investigate transient thermal infrared imaging.

### **WORKSHOP SUMMARY**

The workshop provided an excellent overview of existing and emerging NDE technologies that could be used to inspect composite components in the offshore oil industry. The use of reliable inspection methods will help overcome reliability confidence issues associated with the introduction of new technology, especially for high performance, safety critical applications. Although some NDE methods will naturally evolve into oil industry service without external stimulus; the workshop highlighted the need for certain technology transfer and development to insure that the best NDE methods are available in concert with the introduction of new composite applications. External support, either government, large corporations, or JIP's, is needed to advance new methods such as fiber optics sensors, TRIP metal passive strain sensors, and embedded sensors into practical service ready methods. Discussion also centered on the need for an organization to prioritize the issues and encourage development where needed. Development of an industry plan would help focus limited resources on the critical technical issues as well as provide the forum for the development of a guideline to define the degree of inspection needed for composites used offshore.

## Acknowledgements

The success of the workshop is owed to the NDE technology speakers who provided a concise background review and to the chairmen of the three working groups for their efforts in guiding the discussion. A special note of thanks is extended to Boeing Airplane Company for making a special effort in technology transfer outside their core industry. In addition, the contributions of the attendees were vital to the workshop effort. Finally, the sponsorship of this workshop by the Offshore Technology Research Center membership and the Minerals Management Service is appreciated. A special note of thanks is expressed to Debbie Meador (OTRC) who helped make physical arrangements for the meeting.

## LIST OF ATTENDEES

Aggarwal, Rajiv  
ABB Lummus Global

LaRiviere, Stephen G.  
Boeing Commercial Aircraft

Allevato, Claudio  
Stress Engineering

Laurendine, Tommy  
MMS

Brown, William  
ExxonMobil

Lensing, Chad  
BP

Church, Kevin  
DNV

Leslie, Jim  
ACPT, Inc.

Cole, Bill  
Composites Solutions

Lo, K. Him  
Shell

Crump, Thomas  
Level III, Inc

Magadi, Gopal  
ABS

D'Souza, Antony  
DNV

Markussen, Christian  
DNV

Echtermeyer, Andreas  
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Mercier, Rick  
Offshore Technology Research Center

Esaklul, Khlefa  
BP

Miller, David  
ABS

Hsiao, C.P.  
ChevronTexaco

Morrison, John  
Deep Water Composites

Hsu, TM  
ChevronTexaco

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Oak Ridge National Laboratory

Kalman, Mark  
Halliburton

Ochoa, Ozden  
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Kumar, Amrita  
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Parfrey, Kap  
ABB Vetco Gray

Rogers, Bob  
ExxonMobil

Ross, George  
Stress Engineering

Salama, Mamdouh  
ConocoPhillips

Selvarathinam, Alex  
ExxonMobil

Skogsberg, James  
ChevronTexaco

Smith, Charles  
MMS

Song, Haoshi  
Halliburton Energy Services

Walsh, Thomas  
Hydril

Williams, Jerry G.  
Petroleum Composites

Zhang, Michael  
ExxonMobil

## AGENDA - NDE OF OFFSHORE COMPOSITES WORKSHOP

**Thursday - November 21, 2002**

**Location: Institute of Biosciences and Technology, Texas A&M University  
2121 West Holcombe Boulevard, Houston Texas**

- 7:30 Registration**
- 8:00 Introduction – Workshop Objectives** Jerry G. Williams, Petroleum Composites
- 8:05 Established NDE Technology Principles** Stephen G. LaRiviere, Boeing
- 8:45 Emerging NDE Technology With Potential for Offshore Structural Monitoring**
- 1. Fiber Optic Strain Gages** Jeff Muhs, Oak Ridge National Laboratory
  - 2. TRIP Metal** C.P. Hsiao, ChevronTexaco
  - 3. Shearography** Thomas Crump, Level III
  - 4. Embedded Sensors** Amrita Kumar, Acellent Technologies
- 9:55 Inspection of Offshore Composite Applications** Tommy Laurendine. MMS
- 10:15 Break**
- 10:30 Inspection Strategies and NDE Technologies for Emerging Composite Applications (Participants form a panel)**
- 1. Risers** Kap Parfrey, ABB Vetco
  - 2. Risers & Tendons** Mamdouh Salama, ConocoPhillips
  - 3. Moorings** Jeff Muhs, ORNL
  - 4. Pipes and Tanks** Thomas Crump, Level III
- 11:50 Report on Recent DOE Program Planning Forum** Thomas Crump, Level III
- 12:00 – 12:50 Lunch**
- 1:00 Inspection Experiences in the Aircraft Industry** Stephen G. LaRiviere, Boeing
- 1:25 Instructions to Working Groups**
- 1:40 Working Groups**
- 1. *Designing/Building Inspectability into Composite Products***  
Co-Chair: Bill Cole, Composites Solutions  
Alex Selvarathinam, ExxonMobil
  - 2. *Passive/Active In Situ Monitoring - Underwater/Downhole***  
Co-Chair: James Skogsberg. ChevronTexaco  
C.P. Hsiao, ChevronTexaco
  - 3. *Reliability of Inspection Methods and Candidates NDE Methods for Specific Applications***  
Co-Chair: Mamdouh Salama, ConocoPhillips  
Thomas Crump, Level III
- 3:30 Break**
- 3:45 Working Group Reports**
- 1. *Designing/Building Inspectability into Composite Products***
  - 2. *Passive/Active In Situ Monitoring - Underwater/Downhole***
  - 3. *Reliability of Inspection Methods and Candidate NDE Methods for Specific Applications***
- 4:30 Recommendations and Path Forward**  
(Ozden Ochoa, TA&MU / Jerry G. Williams, Petroleum Composites)
- 6:30 Dinner**