

# Structural integrity monitoring

Review and appraisal of current technologies  
for offshore applications

Prepared by **Atkins Limited**  
for the Health and Safety Executive 2009

# Structural integrity monitoring

Review and appraisal of current technologies  
for offshore applications

**Philip May**  
**Gaspard Mendy**  
**Paul Tallett**  
Atkins Limited  
Saddlers House  
Gutter Lane  
London EC2V 6BR

**David Sanderson (MMI)**

**John Sharp (Independent Consultant)**

With the ageing of the North Sea fleet of platforms and semi-submersibles, the importance of maintaining structural integrity offshore is increasingly recognised and structural inspection plays a significant role in demonstrating ongoing integrity and the potential for life extension. Structural integrity (SI) monitoring can complement existing inspection techniques to provide greater confidence in structural integrity or to reduce inspection cost. It has been found that offshore experience of SI monitoring is limited to date and that current systems are for bespoke applications. This report focuses on fixed steel structures, topsides and semi-submersible hulls.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

© Crown copyright 2009

*First published 2009*

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without the prior written permission of the copyright owner.

Applications for reproduction should be made in writing to:  
Licensing Division, Her Majesty's Stationery Office,  
St Clements House, 2-16 Colegate, Norwich NR3 1BQ  
or by e-mail to [hmsolicensing@cabernet-office.x.gsi.gov.uk](mailto:hmsolicensing@cabernet-office.x.gsi.gov.uk)

### Abbreviations and Acronyms

ACFM	Alternating Current Field Measurement
RACM	Riser and anchor chain Monitoring
AE	Acoustic emissions
AGM	Air Gap Monitoring
API	American Petroleum Institute
CFMD	Continuous Flooded Member Detection
DNV	Det Norske Veritas
DP	Digital Photography
DR	Digital Radiography
ECD	Eddy Current Detection
FG	Fatigue Gauge
GPS	Global Positioning System
HSE	Health and Safety Executive
LD	Leak Detection
MPI	Magnetic Particle Inspection
NFRM	Natural Frequency Response Monitoring
PFP	Passive Fire Protection
RAT	Rope Access Technician
SI	Structural Integrity
SIMoNet	Structural Integrity Monitoring Network
SLOFEC <sup>TM</sup>	Saturated Low Frequency Eddy Current
SM	Strain Monitoring
TOFD	Time of Flight Diffraction
UKCS	United Kingdom Continental Shelf
TR	Temporary Refuge
EER	Environmental Emergency Response
RRF	Relaxation Resonance Frequency
OLM JIP	Online Monitoring Joint Industry Project
WFD	Widespread Fatigue Damage



## TABLE OF CONTENTS

<b>EXECUTIVE SUMMARY .....</b>	<b>1</b>
<b>INTRODUCTION .....</b>	<b>2</b>
<b>1. SCOPE.....</b>	<b>4</b>
<b>2. ASSESSMENT OF HAZARDS, CONSEQUENCES AND APPROPRIATE SI MONITORING TECHNIQUES .....</b>	<b>5</b>
2.1 Hazard and Consequence Identification and Relevant SI Monitoring Techniques .....	5
2.2 Capability of SI Monitoring Techniques .....	8
<b>3. REVIEW OF RELEVANT CODES AND STANDARDS AND PUBLISHED DOCUMENTS .....</b>	<b>9</b>
3.1 Relevant Codes and Standards .....	9
3.2 Review of Published Documents .....	10
3.3 Inspection Requirements .....	10
<b>4. REVIEW OF SI MONITORING TECHNIQUES .....</b>	<b>12</b>
4.1 Acoustic emissions Monitoring .....	12
4.2 Leak Detection .....	14
4.3 Air Gap Monitoring .....	16
4.4 Global Positioning System Monitoring .....	18
4.5 Fatigue Gauge .....	20
4.6 Continuous Flooded Member Detection: Internal .....	22
4.7 Continuous Flooded Member Detection: External .....	26
4.8 Natural Frequency Response Monitoring .....	28
4.9 Acoustic Fingerprinting .....	35
4.10 Riser and anchor chain Monitoring .....	37
4.11 Strain Monitoring.....	39
4.12 Comparison of characteristics of SI monitoring methods.....	41
<b>5. OVERVIEW OF CURRENT INSPECTION TECHNIQUES AND LIMITATIONS .....</b>	<b>44</b>
5.1 Inspection Technique Capabilities.....	44
<b>6. REVIEW OF DAMAGE MECHANISMS FOR WHICH MONITORING CAN COMPLEMENT INSPECTIONS.....</b>	<b>46</b>
6.1 Underwater structure .....	46
6.2 Splash zone.....	48
6.3 Topsides.....	49
6.4 Semi-Submersible Hull Structure .....	49
<b>7. OPPORTUNITIES FOR DEVELOPMENT OF SI MONITORING TECHNOLOGIES FOR LIFE EXTENSION.....</b>	<b>50</b>
<b>8. REQUIREMENTS FOR DEVELOPMENT OF SI MONITORING TECHNIQUES .....</b>	<b>53</b>
<b>9. CONCLUSIONS .....</b>	<b>55</b>
<b>10. REFERENCES .....</b>	<b>57</b>

## Appendices

- Appendix 1** Review of SI Monitoring Published Reports and Documents
- Appendix 2** Comparison of Characteristics of Structural Monitoring Methods
- Appendix 3** SIMoNet Abstracts
- Appendix 4** Review of relevant SI Monitoring Techniques in other Industries
- Appendix 5** Qualitative Review of Inspection and SI Monitoring Techniques
- Appendix 6** Structural Integrity Monitoring of Moorings













Table 1 SI Monitoring Techniques Used to Monitor Damage Parameters

Hazard	Safety critical structural systems	Prevention, mitigation, control measures	Consequences	Relevant SI monitoring techniques (to hazard)
Extreme Weather	Jacket, Foundation, Risers/Appurtenances and their supports	Adequate air gap, design using adequate design wave height, redundancy in design	Loss of stability Loss of airgap (Member buckling Pile failure Member severance)	AGM GPS SM NFRM
Geotechnical Hazards	Foundation	Sea-bed surveys, adequate foundation design, scour allowance, scour inspection, measurement of settlement/subsidence	Loss of airgap Platform tilt Pile failure Pile pull out	GPS AGM NFRM
Fatigue	Jacket, Risers/Appurtenances and their supports, topsides	Design for adequate fatigue life and inspectability, IMR, remote monitoring	Crack initiation Through-thickness cracks Member severance Widespread fatigue damage (Breach of water-tight integrity Loss of stability)	AE CFMD LD NFRM FG SM
Corrosion / materials degradation	Jacket, Topside structures, Risers/Appurtenances and their supports	Corrosion protection, corrosion allowance, CP monitoring, IMR	Loss of wall thickness Cracking Embrittlement Wear Erosion Member buckling Connection to SCE lost (Breach of watertight integrity Loss of stability)	AE NFRM FG
Dropped Object	Jacket, Risers/Appurtenances and their supports, topsides	Design of key members for bow and dent damage, management of crane operations	Member denting / buckling / severance Crack initiation (Breach of water-tight integrity Loss of stability)	NFRM
Ship Collision	Jacket	Design for adequate energy absorption, control on vessel operation, warning systems	Member denting / buckling / severance Crack initiation Breach of water-tight integrity Loss of stability	NFRM
Fire & Blast	MSF, Accommodation module, TR, EER structures, Fire/Blast walls, caissons, exposed jacket legs, risers	Fire/blast walls, PFP, detection and warning systems, deluge system, reduce leaks sources	Loss of structural stiffness Structural overload Blast damage to steelwork	Not generally monitored with SI monitoring methods
Loss of Station Keeping	Moorings, dynamic positioning system	Load measurement		GPS RACM
Change of Use	Jacket, Foundation and Topside structures	Weight management, strengthening/modification	Pile failure Loss of airgap Structural overload	AGM

AGM = Air Gap Monitoring

GPS = Global Positioning System

SM = Strain Monitoring

NFRM = Natural Frequency Response Monitoring

AE = Acoustic Emission Monitoring

LD = Leak Detection

CFMD = Continuous Flooded Member Detection

FG = Fatigue Gauge

RACM = Riser and Anchor Chain Monitoring



















































































































































































