Steel Catenary Risers (SCRs) System Design and Experience

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Steel Catenary Risers (SCR’S)
System Design and Experience

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Presentation Objectives

- Present the opinion that the industry is being rather aggressive in the application of SCR technology based on a limited experience base.

- Highlight the concern that the ‘loop’ between analysis predictions and actual response is not being adequately closed leaving considerable scope for uncertainty and risk.

- Recommend a strategy to best mitigate this risk, improve confidence levels and avoid future failures.

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Basis of Opinions

- Detail design of 3 deepwater SCR projects
- Formal analysis verification on 2 West African projects
- 100+ Studies at conceptual to FEED levels
- $5.0m JIP funding on SCR technology development
SCR Current Applications

- 46 SCRs currently installed to date
- 85% on Spars/TLP – Small motions
- 70% Export service – No $H_2S$ or Slugging
- 96% Gulf of Mexico – Mild environment

- Longest service record is Shell Auger TLP (10 years) BUT SCR already replaced
- Only 2 risers known to have been instrumented – with varying success
- Results from back analysis shows poor ability to predict actual response

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SCR Future Applications

• 114 SCRs planned in next 2-5 years
  • 41% to FPSO
  • 48% to Semi
  • 11% to Spars/TLP
  • 40% in West Africa
  • 60% production

• This is considered a step change in design complexity and risk

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• SCR Criticality

• SCRs are dynamically loaded structures
• Constructed by welding
• All welds contain defects
• All welds have stress concentrations
• Defects grow and eventually propagate

• SCR fatigue failure is a matter of time
  – HOW MUCH TIME?
How much Time to Failure – Interrelated Design Uncertainties

- Load history (Deep currents)
- Riser structural response (VIV, TDP compression)
- Operational conditions (H₂S, slugging)
- Vessel dynamic response (1\textsuperscript{st} and 2\textsuperscript{nd} Order)
- Vessel ballast/loading cycles
- Modelling uncertainties (drag, strakes, TDP interaction, trenching)
- Fabrication quality (Actual defect sizes and properties)
- Material & weld performance (SN and Crack growth rate)

- Significant uncertainty on calculated fatigue life
- Is a factor of safety of 10 appropriate?
SCR Design Approach

- Ensure accurate and complete design basis
- Use a well developed analysis methodology and analytical tools
- Anticipate volume analysis to cover large number of load cases
- Interpret results cautiously to truly understand response
- Schedule for a large number of design iterations/changes
- Conduct ECA linking analysis to fabrication requirements
- Conduct weld qualification & fatigue testing ASAP

- Don’t make mistake of believing a ‘**SCR**’ is a ‘**Simple Catenary Riser**’
TDP Bending Moment Response under compression

Spiky TDP response caused by vessel motion induced compression

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SCR Response Complexities – TDP Compression

MAXIMUM STRESS VS. TDP EFFECTIVE TENSION
6INCH PRODUCTION SCR - RANGE OF PERIODS

55 x 12hr simulations – 55 results!
0.5 – 1.35 yield

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Implement Two Phase Approach to SCR Design

Phase 1

Predict riser response using ‘industry best practice’
Determine requirements for fabrication (ECA)
Implement appropriate fabrication inspection & QA

Phase 2

CLOSE THE LOOP
Monitor riser to determine actual riser response
Update/confirm fatigue life predictions
Update IMR plans

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Typical SCR Fatigue Life Distribution

West of Africa FPSO in 1300m Water Depth - 12" OD SCR
First Order Fatigue Life

Fatigue Life (years)

Length from seabed anchor (m)

TDP

Vessel Hangoff

17m

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Simplistic Monitoring Approach – Using Strain Gauges

1. Obtain TDP Stress Histories
2. Correct for local SCF
3. Rainflow count
4. Assume SN curve
5. Calculate damage
6. Predict remaining life

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Plot of Possible Actual Life

- Highly Localised
- Peak missed by strain gauges

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• Strain gauge density at least 1-2m to capture peak damage
• TDP position uncertain due to
  – Second order motions
  – Installation tolerances
  – Thermal expansion
  – Trenching
  – ‘Walking’ due to cyclic axial expansion
• High strain gauge density may be required over long TDP length
Monitoring using Strain Gauges

- Large numbers of strain gauges required – **impractical**
- Must be bonded to steel pipe - **complex coating interface**
- Bonding has finite life at high temps - **low long term reliability**
- Spot welding introduces crack initiation sites – **reduced fatigue life**
- Difficulty in sealing and protecting gauges– **low reliability**
- Difficulty in routing and protecting wires – **reliability and cost**
- Gauge calibration requirements - **cost**
- Not practical to gauge critical weld locations – **offshore installation**
- Stress correction required for local fatigue details – **uncertain**
- Wall thickness variation and drifting with time - (corrosion/bonding)

**THEREFORE**
- The most practical solution is to measure riser response at a few selected locations and determine peak response through calibrated analytical means

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Recommended Monitoring Approach – GLOBAL Response

1. Monitor GLOBAL response
2. Compare with predictions
3. Identify discrepancies
4. Recalibrate analysis model
5. Rerun analysis & revise life predictions
6. Update IMR

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How is Global Response Best Measured?

- **Rotations and Accelerations**
  - Non intrusive - Does not need contact with steel pipe
    - No corrosion problems
    - No thermal problems
    - No sealing problems
    - Reduced procurement complexity
  - Good reliability and can be replaced
  - Small size and low weight for ease of deployment
  - Signal not effected by local pipe wall corrosion/erosion
  - Does not drift and are not effected by pipe temperature
  - High sensitivity to capture actual response
  - Low component cost and overall system cost

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3D Accelerometer, 3D Gyroscope and Inclinometer Logger

Optional Hardwired Connection

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ROV Deployable Logger

- logger
- locking device
- riser pipe
- bracket
- Handle

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Full Scale Riser Monitoring
- Allegheny

- SeaStar TLP
- 12” dia gas export SCR
- Instrumented by 2H August 1999
- 3300ft (1005m) GoM, top 1/6 straked
- ADCP to 650m

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Logger Axes

X - Axial along pipe length
Y - Orthogonal to pipe in plan of catenary

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Accelerations 10m above TDP

West of Africa FPSO in 1300m Water Depth - 12" OD SCR

Acceleration in Logger Local Axis - 10m above TDP

Hs=1.0m: 0.6m/s²  Hs=1.9m: 0.8m/s²

Accelerations 10m above TDP

Hs=1m 0.03m/s²  Hs=1.9m 0.06m/s²

Logger Resolution 0.001m/s²

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Logger Sensitivity Confirmation

Sensor Output during applied Peak to Peak Accel = 0.011m/s², 4.6s Period

- **Peak to Peak Acceleration**: 0.011m/s² (0.03m/s² required)
- **Capability**: 0.003m/s² Peak to Peak
- **Noise Floor**: 0.00036m/s² RMS

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Recommended Monitoring Approach

- Do not try and capture fatigue peaks – Global response
- Angles and rotations are recommended parameters to measure
- Carefully plan how data will be processed prior to implementation
- Ensure suitable logger design with respect to sensitivity, noise
- Optimise logger locations and logging schedules
- Appreciate complexity of signal processing
- Use processed data to calibrate analysis and recalculate fatigue life
- Short term monitoring (1-2 years) feasible / acceptable
- Stand alone loggers retrieved annually is acceptable for TDP fatigue
- Hardwired loggers at upper flex joint gives important real time data
- At least one riser on every development should be instrumented
Summary and Conclusion

• SCR technology is not as mature as many people would like to think and is generally more complex

• A number of key design uncertainties remain

• Application of SCR technology to higher motion vessels and for production applications presents increased risk

• THE ‘LOOP MUST BE CLOSED’ BY APPROPRIATE MONITORING TO ALLOW CALIBRATION OF ANALYSIS PREDICTIONS AND ASSUMPTIONS ON A PROJECT BASIS