STRUCTURAL INTEGRITY MANAGEMENT OF OFFSHORE STRUCTURES

IEOT Panvel

05.12.2017
ONGC operates 281 fixed offshore platforms in Western offshore, India

<table>
<thead>
<tr>
<th>Platform Type</th>
<th>Quantity</th>
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<tr>
<td>Process Platforms</td>
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<td>Well Platforms Connected to Process Complex</td>
<td>11</td>
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<td>Living Quarters</td>
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<tr>
<td>Unmanned Well Platforms</td>
<td>205</td>
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<td>Flare Platforms</td>
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Concern for adequacy of old structures was prompted by

- Hurricane Juan - 1985
- Hurricane Andrew – 1992
API–RP-2A introduced section 17 as a supplement to the 20th edition—the recommended practice for assessment of existing platforms.
Structural integrity management (SIM) is the process for demonstrating a structure’s fitness-for-purpose over its entire life.

SIM is a process for managing the effects of deterioration, damage, changes in loading, and accidental overloading.
SIM PROCESS

DATA

- Managed system for the archival and retrieval of SIM data and other pertinent records

EVALUATION

- Evaluation of structural integrity and fitness-for-purpose; development of remedial actions

STRATEGY

- Overall inspection philosophy and strategy and criteria for in-service inspection

PROGRAM

- Inspection Detailed work scopes for inspection activities and offshore execution to obtain quality data
DATA

ORIGINAL DESIGN DATA
AS BUILT DRAWINGS; EQUIPMENT LAYOUT; DESIGN DOCUMENTS; STRUCTURE MODELS; SOIL REPORT; WEIGHT CONTROL REPORT

INSPECTION FINDINGS THROUGHOUT OUT LIFE
CORROSION; DENTS; DAMAGES; CRACKS; HOLES

CHANGE / ADDITION OF LOADINGS
MODIFICATIONS

DATA → EVALUATION → STRATEGY → PROGRAM
ASSESSMENT INITIATORS

- Addition of facilities such as wells (clamp-on), risers, deck modification, etc.
- Changes in design codes resulting in increased environmental loading
- Damages due to vessel collision
- Damage due to fatigue and corrosion increases with increase in age
- Use of structure beyond design life

DATA ➔ EVALUATION ➔ STRATEGY ➔ PROGRAM
INCREASED ENVIRONMENTAL LOADING

25-30% increase in Wave loading due to Modifications in the design co-efficient in API-RP-2A in 1993

10-12% increase in wave loading on the platforms due to revision in marine growth criteria from 38mm to 100mm
LIFE EXTENSION PROJECT

- 19 WHP & 3 Process Platforms
- Water depth ranges from 50 to 90m
- Designed based on API-RP-2A
- Design life 25yrs
- Required up to 2030

Life extension studies are therefore required to ensure their fitness for purpose for the extended life
ASSESSMENT PHILOSOPHY

NO INCREASE IN RISK ASSOCIATED WITH LIFE SAFETY OR ENVIRONMENTAL RISK

AN ACCEPTABLE LEVEL OF ECONOMIC RISK, LEFT TO THE OPERATOR’S DISCRETION
# Assessment Philosophy

## Assessment Criteria As Per API-RP-2A

### Design Level Analysis

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<th>Consequence of Failure</th>
<th>Life Safety</th>
<th>Criteria</th>
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<td>High</td>
<td>Manned</td>
<td>85% of Lateral Loads for 100 year RP</td>
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<tr>
<td>Low</td>
<td>Unmanned</td>
<td>50% of Lateral Loads for 100 year RP</td>
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ASSESSMENT PHILOSOPHY

ASSESSMENT CRITERIA AS PER API-RP-2A
ULTIMATE STRENGTH ANALYSIS

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<th>Criteria</th>
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<td>RSR 1.6</td>
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<td>LOW</td>
<td>Unmanned</td>
<td>RSR 0.8</td>
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LIFE EXTENSION OF WELLHEAD PLATFORM WHP-A:

- Installed in Mumbai High South in 80’s in a water depth of 77m

Production Details:
- 12 Wells (9+3)
- 6 risers

- Pile Configuration: 4+2; Pile dia.=1.372m
- One 3 tier boat landing on East face
DESIGN LEVEL ANALYSIS (WSD)

- Clamp-on wells, risers, RP etc, are added to the existing structures
- Modeling of damaged members
- Marine growth of 100 mm from (+) 6m to (-) 30m and 50 mm up to sea bed considered
- Analysis carried out with wind, wave and current for 8 directions
- Piles (95 / 77 m below seabed) checked for load carrying capacity and stresses
- Members and joints checked for yield / stability and punching shear

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Design Level Analysis: Re-analysis Results

Overstressed Components:

a. 6 Members, Max. UC=1.243
b. 3 Joints, Max. UC=1.280
c. 4 out of 6 piles found to be overstressed, Max. UC=1.382 for Pile B2. Piles are found to be safe in Factor of safety check

Row 2 Piles (A2 and B2) found to be most overstressed with highest UC under South direction (Under Tension)

2 no. X-brace joints located at Row-A and Row-B are found to be overstressed,
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Non-linear Ultimate Strength Analysis

From component level to Global structural level with target RSR of 1.323

Pile failure (for both main pile A2 and B2) and joint failure observed

Collapse load less than target RSR
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Additional Pile Requirement
Chord members **0248-0249 & 0252-0253** (to be grouted) for joint **0253 & 0257** respectively as highlighted in blue, EL (-) **52.76m**

Member **0001-404L**, to be grouted highlighted in **blue**, Row-B (b/w EL(-)29.76 & EL(-)52.76m)
Fatigue Analysis

- Offshore tubular joints are susceptible to fatigue damage due to wave loading and stress concentration.
- A Design Fatigue Factor (DFF) of 10 is considered for critical joints.
- S-N curves and Stress Concentration are major Factors which govern the fatigue damage.
- 80 joints were found below the target fatigue life.
STRATEGY

- Inspection on regular fixed intervals
- Risk-based inspection

Risk = Probability of Failure × Consequence of Failure
**PoF increases with time due to time dependant degradation**

**Inspection provides more information on status of structure and thus reduces PoF**

**Mitigation reduces the consequences and thus reducing overall risk**
Probability of Failure can be calculated using simplified structural reliability analysis with a limit state function:

\[ g(U, D) = U - D \]

Where \( U \) is uncertainty wrt fatigue capacity and \( D \) is Fatigue Damage:

\[ D = T \times v_o \times D_{cycle} \]
## ACCEPTANCE CRITERIA PoF

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<th>Category</th>
<th>Safety factor</th>
<th>Lowest allowable fatigue life</th>
<th>Accumulated Probability of fatigue failure at end of service life</th>
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<td>L1 - Failure critical</td>
<td>10</td>
<td>200</td>
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<td>L1 - Not failure critical and L2 and L3 failure critical</td>
<td>5</td>
<td>100</td>
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<td>L2 and L3 not failure critical</td>
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<td>50</td>
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![Graph showing Probability of fatigue failure as a function of service time](image.png)
Consequence of Failure

Probability of Collapse for given probability of fatigue failure can be calculated using simplified structural reliability analysis using limit state function

\[ g = C - L = C_{\text{calc}} \times X_c - L_j \times X_j \]

\[ = RSR \times X_c - H_{\text{wave}} \times X_j \]

\[ C = \text{capacity} \]

\[ L = \text{LOAD} \]
RISK MATRIX

- Risk matrix

- Detailed inspections needed

- No detailed inspections needed

- Conditional probability of failure

- Accumulated probability of failure

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INSPECTION METHODS

NON DESTRUCTIVE METHODS

• BELOW WATER
  • FLOODED MEMBER DETECTION (FMD)
  • EDDY CURRENT (EC) OR MAGNETIC PARTICLE INSPECTION (MPI)

• ABOVE WATER
  • EDDY CURRENT OR MAGNETIC PARTICLE INSPECTION (MPI)

DATA ➔ EVALUATION ➔ STRATEGY ➔ PROGRAM
## PLATFORM WHP-A

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