LIFE-CYCLE ASSESSMENT OF OFFSHORE PLATFORMS

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Part I – Offshore Structure Categories
Offshore Structures Categories

- Drilling ship
- Tension leg
- FPSO
- Semi-sub
- Jack-up
- Fixed platform
- Subsea wells
Offshore structures may be subdivided in the following categories:

1. **Drilling units:**
   - Exploration;
   - Drilling.

2. **Production units:**
   - Production.

3. **Support units:**
   - HLV;
   - SV;
   - Lay-barges;
   - Submarine units;
   - etc.
Development of a project is composed of several successive stages having requirements that strongly influence the choice of structures:

1. **Initial phase of search for new fields:**
   - Mobility from field to field;
   - Operations strongly influenced by environmental conditions.

2. **Production phase:**
   - Station-keeping capacity;
   - High productivity;
   - Operational availability (w.r.t. severe environmental conditions).
Environmenta parameters:
- Water depth;
- Meteocean design conditions;
- Geotechnical parameters;
- Seismicity.

Parameters dependent on reservoir and rig:
- Number of wells and expected production life;
- Depth of field;
- Hydrocarbon type (oil/gas) and content (addressing process design);
- Weight of drilling and process topsides;
- Geometrical characteristics of drilling system.

Parameters dependent on market and company conditions:
- Plants daily rate;
- Availability of national industries;
- Standardization or extrapolation of well known schemes;
- Scheduling for starting of production (based on economics);
- Exporting system of products.
Design of Offshore Structures

Design situations
During the design of offshore structures, many situations shall be considered in order to obtain the most critical design condition for all the structural components:

• **Pre-service situations** (i.e. fabrication, assembly, load out, transportation, installation)
• **In-place**;
• **Removal**.

**Design Life of 20-25 years** (based on target production)
Addressing

• Extreme environmental loads return period
• Fatigue and CP issues
Part II – Existing Platforms Life Extension
Increasing number of existing fixed offshore platforms, exceeding the original design life, that need to be maintained in production. The original economic target is often changed due to revised benefits in maintaining the platform in production.

The platform is reassessed to verify and possibly update the residual structural capability, based on current (fatigue and corrosion) conditions.

The existing structure is fit-for-purpose when the risk of structural failure leading to unacceptable consequences is adequately low.
The required safety target shall be demonstrated for the specific site conditions and given operational requirements.

The original design target was ensured (typically with respect to the extreme environmental event, related in turn to a prescribed design life) introducing some conservativisms

=> Uncertainties in platform to be designed

Reassessment is possible by taking into account the new information and measurements due to the actual behaviour of the platform

=> Platform as its own Full Scale Model

=> Reduced Uncertainties

=> Design Life Extension
NORMATIVE DEVELOPMENT

API
- Early 1990’s: Section 17 (Assessment of Existing Platforms), guidance for evaluating the fitness-for-purpose of existing fixed offshore platforms.
- 2005: revision of Section 17 (“supplement” to API RP 2A), development of a new RP, preliminary called RP 2SIM.

In Gulf of Mexico there are more engineering works for re-assessment than new design.

ISO
- Mid-1990’s: 19900 suite of guidelines to address design requirements for all types of offshore structures, including fixed steel structures (ISO 19902 in 2007).

According to both API and ISO, the actual structural performance shall be revised by introducing the present conditions of the structure.
PART B (STRUCTURES)
CHAPTER 6 – ASSESSMENT OF EXISTING STRUCTURES
1 General
2 Assessment Process
   2.1 Assessment data gathering
   2.2 Inspection on the current platform status
      2.2.1 General requirements
      2.2.2 Requirements for submarine survey
      2.2.3 Level I
      2.2.4 Level II
      2.2.5 Level III
      2.2.6 Level IV
      2.2.7 Survey Specification
      2.2.8 Survey Procedure
   2.3 Definition of the up-to-date platform model
   2.4 Definition of the loads
   2.5 Verification of the platform structure
      2.5.1 Resistance assessment
      2.5.2 Fatigue assessment
      2.5.3 System assessment
      2.5.4 Reference values for the Reserve Strength Ratio
1 – Data Gathering (1 of 4)

- General information
  - Date of installation
  - Original and current platform use and function
  - Location, water depth and orientation
  - Platform structural type (4-6-8 legs jacket etc.)
  - Number of wells, risers and potential pollution rate
  - Other site specific information, manning level
- Original design data
- Construction and fabrication data
- Platform history data
1 – Data Gathering (2 of 4)

- General information
- Original design data
  - Design drawings and material specifications
  - Design code and design URs of the structural components
  - Environmental data (wind, wave, current, seismic)
  - Deck clearance elevation
  - Operational criteria (deck loading and equipment arrangement)
  - Soil and foundation data
  - Number, size and design penetration of piles and conductors
  - Appurtenances - list and location as designed
- Construction and fabrication data
- Platform history data
1 – Data Gathering (3 of 4)

- General information
- Original design data
- Construction and fabrication data
  - As-built drawings
  - Fabrication, welding and construction specifications
  - Pile and conductors driving records and grouting records (if applicable)
- Platform history data
• General information
• Original design data
• Construction and fabrication data
• Platform history data
  • Environmental loading history and performance of the platform during past extreme environmental events
  • Operational loading history (happened collision and accidental events and possible damages reported)
• Survey and maintenance records
• Repairs description, analyses, drawings and dates
• Modifications description, analyses, drawings and dates
Aimed to integrate and complete the required information

Present condition of the platform to be determined by specific field inspections and on-site measurements

• Topside survey

• Underwater survey:
• Topside survey:
  • Deck actual size, location and elevation;
  • Deck existing loading and equipment arrangement;
  • Field measured deck clearance elevation;
  • Wells-number, size and location of existing conductors;
• Underwater survey
• Topside survey

• Underwater survey:
  • GVI of the jacket and seabed
  • CVI and NDE (e.g. by MPI/ACFM/FMD) of a selected (limited) number of nodes (such a limited sample is selected as representative following to the fatigue design checks and structural categorization)
  • WTM of several members

• CPM (potential measurements, anodes, volumes)

• MGM
Geometric and material data revised as per the inspection results.
- Proper representation of any damage and modification occurred
- Fatigue and corrosion conditions
Dead and Live loads based on updated info on actual jacket weight (from installation) and topside layout

- Extreme and operational environmental loads are to be defined in accordance with the recognized standard methods, given the data collected w.r.t. dead, live and environmental loads
- Environmental loads (extreme values and distribution) predictions made at design stage can be revised according to
  - Measurements at the site
  - Measurements at nearby sites, or
  - New hindcast studies based on updated databases
REASSESSMENT PROCESS
5 – Strength Assessment

Static
Dynamic
Fatigue
Seismic
System
Push Over
System Reliability

Dedicated Software: SACS, OCEANOS

• Static analysis for extreme and operational loads
• Jacket structural safety checks against API/ISO/RINA Rules for
  • D+L+E loading conditions
  • Verification of tubular members (C+B+H, etc.) and tubular joints (punching shear)
  • Pile bearing capacity
Limited failures of individual components are accepted if the reserve against overall system failure remains acceptable. The platform has shown appropriate performance via full-scale model, i.e. the platform itself.

Yielding or failure of individual components is acceptable, if the remaining parts of the structural system have sufficient reserve strength to redistribute the action.

A pushover analysis is used to demonstrate that the safety factor against failure of the whole structural system meets acceptable levels (RSR target).
Ultimate strength analysis by elasto-plastic analysis. Environmental loads increase up to the whole system collapse. The verification is considered satisfied when the collapse load will result “appropriately” greater than the design load.

Non-linear push-over
- Loads are applied in sequence:
- Dead and live loads are applied to their nominal value.
- 100-year environmental load vector (wave, current and wind) is applied and increased until the structural collapse of the whole platform.
- RSR: ratio between base shear resistance and design load (Rd/F100)
• When it is not possible to show that the structure is acceptable even by RSR:
  • decreased reliability of the overall system could be acceptable, provided that the consequences of failure are acceptable for both the life and the environment
    • e.g. de-manning the platform and provide for safety system to close the wells in case of foreseen extreme environmental event
  • actual system reliability evaluation by SRA to determine maximum extreme wave (return period) and relevant residual life
System reliability analysis.
Statistical evaluation of both the strength and the environmental load, in order to finally evaluate the yearly probability of collapse in storm conditions.

The required safety target can be related to the actual system capacity of the platform, measured by the RSR, and then introduced in a system reliability assessment capable to eventually determine the actual residual life of the platform and maximum return period of the extreme environmental loading that the platform is still capable to withstand.

A notional yearly probability of collapse of the platform may be evaluated by a simplified procedure, starting from the evaluation of the environmental forces F1 and F100 respectively. The maximum yearly load is associated to the maximum annual wave height. Therefore the environmental forces are characterized by a yearly probability of exceeding equal to the associated wave height.
Dynamic and Probabilistic Fatigue Analysis

- The fatigue analysis inside a reassessment process should be performed on a probabilistic basis.
- Fatigue is a process dominated by uncertainties of many kinds, generally of random nature.
- For this reason, in order to ensure a low risk of failure, the code requirements are usually very conservative and provide, on the average, a high safety margin. As a consequence, the conventional fatigue analysis carried out on old platforms for a life extension would not in many cases meet current code requirements.
- Probabilistic analysis can give the most exhaustive assessment of criticality to fatigue failure for existing structures, being capable to implement inspection history.
A Spectral Fatigue Assessment is normally carried out for existing jackets:

- Stress range transfer function determination
- Environmental load spectrum definition
- Stress range response spectrum calculation
- Fatigue damage evaluation
- Capable to implement monitoring outcomes
- To calibrate frequency response
By adopting a reliability based fatigue approach it is possible to account for a new possibility, which is of paramount importance to the management of structural safety:

• The results of the in situ inspections can be utilized to update, in quantitative terms, the structural reliability evaluation

• The reliability index is evaluated as a function of the time passed since installation, the expected endurance of the node at the design stage and the results of the node inspection
FUTURE INSPECTIONS PLANNING

Inspection outcomes combined with fatigue predictions:
• Reliability approach to update fatigue safety margin and to plan future inspections
  • Fatigue safety margin as $\beta(t)$
  • Updating of $\beta$ at a given time of inspection
  • Reducing uncertainty $\Rightarrow$ increasing safety margin, particularly in case that no cracks are detected
Following the reassessment analyses, some management decisions are required for the identification of remedial measures, in case that the structure does not meet the assessment requirements.

Mitigation actions are defined as modifications or operational procedures that reduce loads, increase capacities, or reduce consequences:

- Repairs
- Strengthening measures

As regards in particular the fatigue topics, in order to keep the structural reliability over an acceptable limit, it is necessary to provide for an inspection plan:

- To carry out NDE (Non Destructive Examination) of the most critical nodes.

In addition to engineering assessment, the life extension of the jacket is subject to the provision of an updated IMR Plan set by using:

- the newly performed fatigue analysis
- The outcomes of the inspections actually carried out
  - CVI of selected joints (MPI + FMD)
  - WTM
  - CPM
  - MG Cleaning
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Thanks for the attention!
Any question?