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DESIGN / ANALYSIS PROCEDURES FOR FIXED OFFSHORE PLATFORM JACKET STRUCTURES

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ABSTRACT- *THE KINDS OF TECHNOLOGY CURRENTLY BEING APPLIED TO THE DESIGN, CONSTRUCTION, INSTALLATION AND OPERATION OF OFFSHORE STRUCTURES FOR OIL AND GAS EXPLORATION AND PRODUCTION ARE QUITE SOPHISTICATED AND INCLUDE MANY EXAMPLES OF INNOVATIVE CONFIGURATIONS AND APPROACHES. API —RECOMMENDED PRACTICE FOR PLANNING, DESIGNING, AND CONSTRUCTING FIXED OFFSHORE PLATFORM CONTAINS ENGINEERING DESIGN PRINCIPLES AND GOOD PRACTICES THAT HAVE EVOLVED DURING THE DEVELOPMENT OF OFFSHORE OIL RESOURCES. OBJECTIVE IS TO DESIGN AND CONSTRUCTION OF PLATFORM WITH HELP OF API FIXED OFFSHORE PLATFORMS - WORKING STRESS DESIGN. THE DATA USED FOR DESIGNING ENVIRONMENTAL CONSIDERATIONS SUCH AS WIND, WAVE AND CURRENT, STRUCTURAL, FATIGUE, FOUNDATIONS, INSTALLATION ETC. AND OCEAN ENVIRONMENT. FROM THESE DATA EFFECTIVE STRUCTURE IS DESIGNED.*

Keywords- *Jacket Structure, Static Analysis, Wave Loading, Lift analysis, Load out analysis*

I. INTRODUCTION

The most common offshore solution for shallow to medium water depths takes the form of piled-jacket with deck structures, all built in steel. The size and the weight of the jacket structure depends on the number of facilities to be provided on the deck (typically referred to as topsides), water depth, environmental loads imposed on the structure. The number of legs, plan dimensions and brace member configuration are function of topsides area requirement, loading, water depth and environment. Lift, load out, transportation to offshore location and installation on location. For inplace conditions the structure is designed to resist combinations of design loads that include self-weight and other operational loads as well as environmental loads due to wave, current, wind, earthquake etc. The most commonly used code for designing jacket structures is API-RP2A WSD (Working Stress Design). Other codes include DNV rules and Lloyd's rules. Topside structures are typically designed using the AISC-code along with the AWS code for welding.

II. DESIGN FOR INPLACE CONDITION

The first premise in the design of jackets is that the jacket natural period is well separated from the wave periods normally encountered in the in place condition. This ensures that the structure responds in a statically and not dynamically to the imposed wave loading. Typically jackets have natural periods in the first mode ranging from 2 to 3 seconds. The wave period is typically between 10 to 16 seconds. In such a case the structure can be analysed for the forces imposed on it quasi-statically. In case the structure natural frequency approaches the predominant wave frequency then the analysis must take care of response amplification at the wave period.

Environmental Loads - Environmental loads are those caused by environmental phenomena such as wind, waves, current, tides, earthquakes, temperature, ice, sea bed movement, and marine growth. The meteorological and oceanographic conditions (typically referred to as met ocean data) at the jacket platform location are determined by experienced and expert consultants. An example of this is Glen's report which is typically used for design of ONGC platforms.

Wind

Wind forces are exerted upon that portion of the structure that is above the water, as well as on any equipment, deck houses, and derricks that are located on the platform. The wind speed may be classified as: gusts that average less than one minute in duration, and sustained wind speeds that average one minute or longer in duration.
Once the wind speed at the desired elevation has been computed the wind force at this elevation may be computed as:

$$F' := \left(\frac{\rho}{2}\right) \cdot U^2 \cdot C_S \cdot A$$

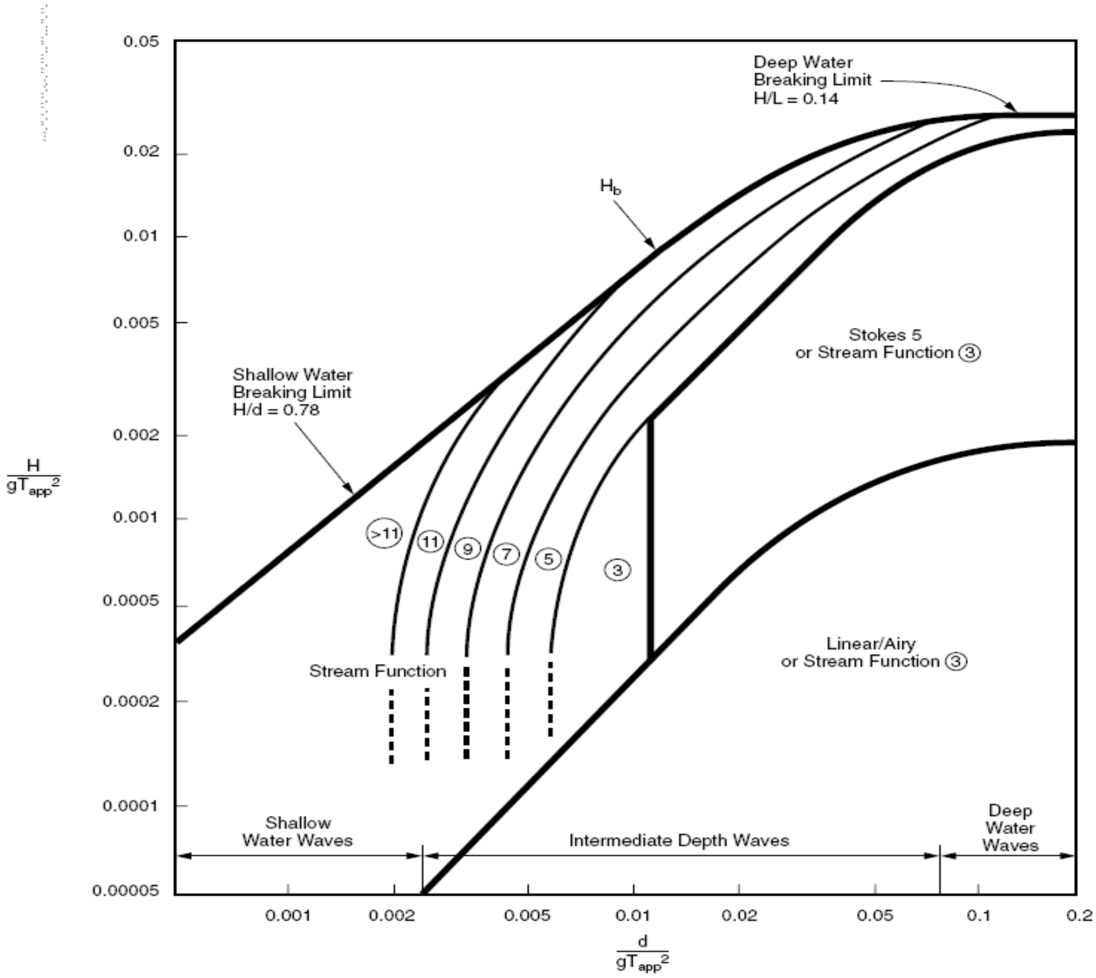
where
F = wind force,
 ρ= mass density of air, (slug/ft3, 0.0023668 slugs/ft^3 for standard temperature and pressure),
u = wind speed (ft/s),
Cs = shape coefficient,
A = area of object (ft^2).

Waves

The wave loading of an offshore structure is usually the most important of all environmental loadings for which the structure must be designed. The forces on the structure are caused by the motion of the water due to the waves which are generated by the action of the wind on the surface of the sea.

Wave Theories

Once the appropriate wave theory has been selected the forces on the jacket members can be computed from Morrison's equation after accounting for effects like Doppler effect, effect of current on wave kinematics, wave spreading, current blockage factor, marine growth and conductor shielding factor etc. Consideration for all the effects mentioned is detailed in API-RP2A.



H/gT_{app}^2: Dimensionless wave steepness
d/gT_{app}^2: Dimensionless relative depth
H: Wave height
H_b: Breaking wave height
d: Mean water depth
T_{app}: Wave period
g: Acceleration of gravity

Figure-1 Wave theory selection (Reference- API RP-2A)

Wave Forces

Wave loads on submerged jacket members can be computed as a summation of drag loading and inertial loading. The equation summarizing these forces is called Morrison's equation.

From API-RP2A Morrison's equation for wave loading is given below

$$F' := F_D + F_I$$

$$F' := C_D \cdot \frac{w}{2g} \cdot A \cdot U^2 + C_m \cdot \frac{w}{g} \cdot V \cdot \frac{\delta U}{\delta t}$$

Where

F = hydrodynamic force vector per unit length acting normal to the axis of the member, lb/ft (N/m),

F_D = drag force vector per unit length acting to the axis of the member in the plane of the member axis and

U,
lb/ft (N/m),F_I = inertia force vector per unit length acting normal to the axis of the member in the plane of the member axis and αU/αt, lb/ft (N/m),
C_d = drag coefficient,
w = weight density of water, lb/ft3 (N/m^3),
g = gravitational acceleration, ft/sec^2 (m/sec^2),
A = projected area normal to the cylinder axis per unit length (= D for circular cylinders), ft (m),
V = displaced volume of the cylinder per unit length (= $\pi D^2/4$ for circular cylinders), ft^2 (m^2),
D = effective diameter of circular cylindrical member including marine growth, ft (m),
U = component of the velocity vector (due to wave and/or current) of the water normal to the axis of the member, ft/sec (m/sec),
U| = absolute value of U, ft/sec (m/sec),Cm = inertia coefficient,
δU/δt = component of the local acceleration vector of the water normal to the axis of the member, ft/sec^2 (m/sec^2) The values of Cd and Cm depend on the wave theory used, surface roughness and the flow parameters. According to API-RP2A, CD = 0.65 to 1.05 for smooth and rough conditions respectively and CM = 1.6 to 1.2 for smooth and rough conditions respectively.
The total wave force on each member is obtained by numerical integration over the length of the member. The fluid velocities and accelerations at the integration points are found by direct application of the selected wave theory.

III. DESIGN FOR PRE-SERVICE CONDITIONS

These loads are temporary in nature and arise during fabrication and installation of the jacket, deck or modules on the deck. Typically, during the fabrication and erection phases of the project, lifts of various structural components generate lifting forces which are transferred to the structure. In the installation phase forces are generated during platform loadout, transportation to the site, launching and upending, as well as during lifts related.

Lifting - Lifting forces generated and consequently imposed on the jacket structure depend on the weight of the structural component being lifted, the number and location of lifting eyes used for the lift, the angle between each sling and the vertical axis and the conditions under which the lift is performed. All members and connections of a lifted component must be designed for the forces resulting from static equilibrium of the lifted weight and the sling tensions. A typical offshore lift operation is shown in figure2.

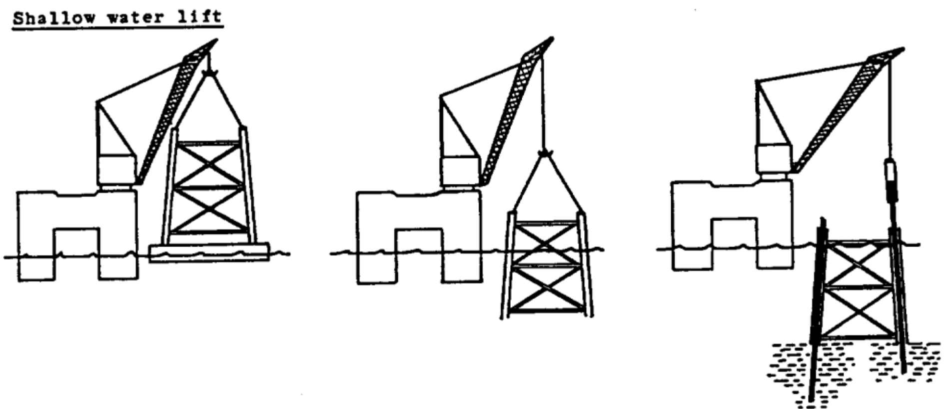


Figure-2 Jacket lift (Reference- Handbook of offshore engineering subrata k chakrabarti)

Load-out - Once the jacket, deck or module has been fabricated it needs to be moved from the yard to the transportation barge which will then transport it to the offshore location where it is installed. The loadout process leads to the generation of forces when the jacket is loaded from the fabrication yard onto the barge. Loadout could be carried out by:(1) Lift (2) Trailer (3) Skidding

Tow of structure

Once the loadout process has been completed the next stage is the transportation to the offshore location on the transportation barges. These transportation barges are not self-propelled but are towed by means of tug boats. During the transportation, inertial forces are generated when platform components (jacket, deck) due to the motion of the barge when it is being towed in the open sea.

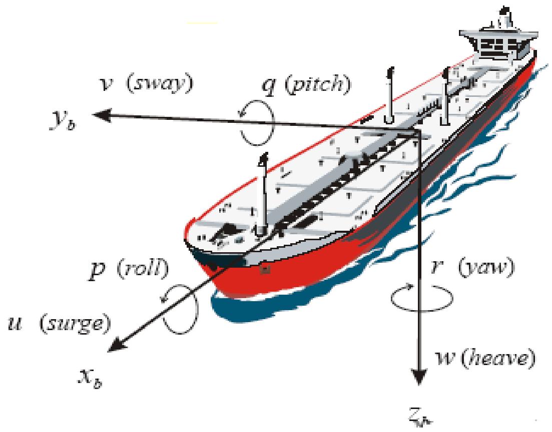


Figure 3 Barge motions (Source-internet)

Launching and Upending - Once the jacket has been transported to the offshore location it is sitting on the transportation barge. The temporary transportation fastening in the form of sea-fasteners and lashings is removed. The next objective is to launch the jacket into the open sea after which it is straightened and released so that it can sit vertically on the sea-bed. There are five stages in a launch-upending operation (shown schematically in figure 4):(1) Jacket slides along the skid beams (2) Jacket rotates on the rocker arms (3) Jacket rotates and slides simultaneously (4) Jacket detaches completely and comes to its floating equilibrium position (5) Jacket is upended by a combination of controlled flooding and simultaneous lifting by a derrick barge.

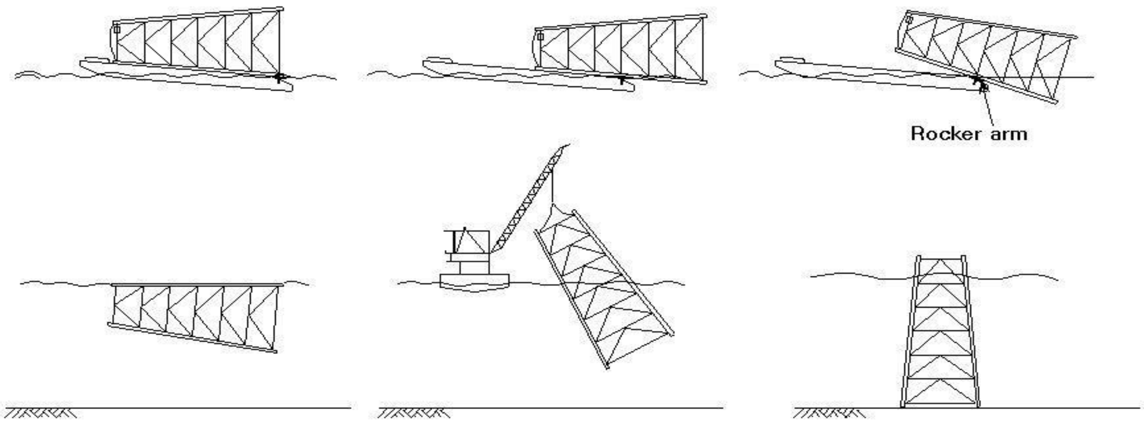


Figure 4: Launching and Upending of Jacket

(Reference- Handbook of offshore engineering subrata k. chakrabarti)

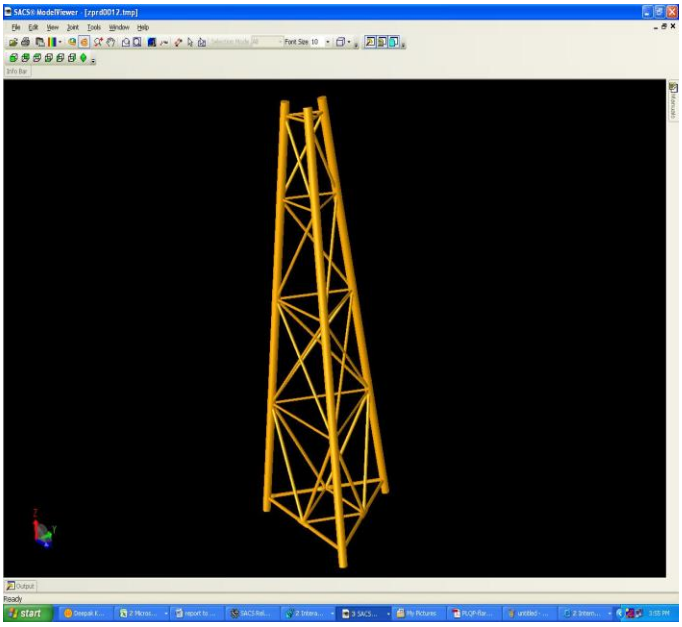
IV Structural modeling

Structural modeling of jacket type structures is done by SACS 5.2 (Structural analysis & computation system). All members are assumed to connected centre to centre. Appropriate effective lengths have been provided for all members according to structural arrangement. All members have been assigned members property by defining different member group in SACS software.

Description of jacket

(1) Jacket type = Tripod type
(2) Number of main columns = 3
(3) Pile type = Ungrouted
(4) Pile connectivity elevation = 7.5

(5) Mud line elevation = -56.6
(6) Pile Stub elevation = -60.1
(7) Working point elevation =8.5
(8) Other elevations = 6,-6,-22,-   40



Analysis Methodology
The pre-service analysis of the Flare tripod is performed in following manner-
The SACS model of the Tripod has been prepared based on Tripod drawings issued by EIL and it has been analyse to verify the structural strength of members and joints for Load-out, Lift, and Transportation & during on–bottom condition. Any member/ joint overstressing are highlighted & appropriate solution for overstressing is also shown. The results of the analysis for load-out, sea transportation, lift & on-bottom are presented in section 4.0.

Load-out Analysis Criteria
Load-out analysis has been carried out with the following criteria.
The Tripod is proposed to be loaded out using trailers.
The trailers arrangement uses load out girder at Tripod EL (-) 6.00 and (-) 57.2 and hence no intermediate support on Tripod braces are used.

The horizontal breaking load is applied to all structural members in the direction of the load out calculated as 8% of the weight of each element.

Transportation Analysis Criteria
Transportation analysis of the Tripod has been carried out for following two cases.
Transportation analysis is carried out as follows: -.
The vertical load from the Tripod is taken by the stubs located at EL (-) 6.00 m and (-) 51.612 m for gravity load condition (Static case), the effect of inclined sea fastening members in vertical direction is neglected (Gravity load shall not be taken by sea fastening members). Analyses has been carried out by using Gap module as vertical stub near mud-mat is only a compression element and cannot take tension as jacket is not welded to this stub. Barge Motion parameters has been selected based on EIL Engineering Design Basis (Structural). Roll angle of 20 degrees and pitch angle of 12.5 degrees with a period of 10 sec is used. A heave acceleration of ±0.2G is associated with the roll and pitch motions.

Lift Analysis Criteria
Lifting is being carried out using 4 slings 3 slings attached at upending pad-eyes & at 1 by Trunnion on skirt sleeve.
The lift points are proposed at EL (+) 6.5m on upending pad eyes and EL (-) 57.2m on skirt pile sleeve on Row B2.

Load-out Analysis
Load-out analysis has been performed based on criteria described in section 3.3 with all the members as per GFO drawings. The computer model shows the Tripod together with the load-out girder location and arrangement. The Tripod

is supported on load-out girders at EL (-) 6.0m and EL (-) 57.2m. The results of the analysis indicate the failure of members highlighted in Figure 5. The summary of failures and upgrade required is given in Table 1 and 2

Table 1 Summary of failure members during Load-out

Member Name	Member Size	Group Name	Member UC	Upgrade Member Size	Remarks
11-12	Φ356x12.7 thk	H4	1.002	Φ356x12.7 thk	Member yield strength is changed from 36 ksi to 50 ksi

Table 2 Summary of failure Joints During Load-out

Joint No	Chord Member	Brace Member	Joint UC	Remarks
26	26-150	26-211	1.263	Internal rings are proposed.
22	22-149	22-208	1.254	
18	18-56	18-180	1.085	
19	19-55	181-19	1.085	

Sea Transportation Analysis

The Tripod is supported on at EL (-) 6.0 m and EL (-) 51.612 m and sea fastening is provided at EL (-) 6.00m, (-) 40.00m and (-) 51.612m. The summary of failures and upgrade required is given in Table 3

Table 3 Summary of failure Joints during Transportation

Joint No	Chord Member	Brace Member	Joint UC	Remarks
159	147-159	156-159	2.197	External gusset plate will be provided
158	146-158	158-155	2.164	
156	65-156	156-159	2.037	Internal ring will be provided
155	66-155	158-155	2.011	

Note – There is no member-UC failure for Transportation analysis.

Lift /Upending Analysis

The lifting Sling locations are in EL (+) 6.5m & EL (-) 57.2m. The Lifting/upending analysis is done for 5 cases namely -
Case: 1 - when jacket fully in air in horizontal position
Case: 2 - when jacket 30 Degree rotated from horizontal & partially in water
Case: 3 - when jacket 45 Degree rotated from horizontal & partially in water
Case: 4 - when jacket 60 Degree rotated from horizontal & partially in water
Case: 5 - when jacket 90 Degree rotated from horizontal & partially in water
Out of these 5 cases case-1 is found critical, so results of case-1 & up gradation of case-1 is shown in report with taking care of Failure of other cases. After analysing with upgraded member sizes for case-1, other cases also come safe for UC-failure.

Table 4 summary of failure members during Lift

Member Name	Member Size	Group Name	Member UC	Upgrade Member Size	Remarks
6-81	Φ406x15.9 thk	H5	2.422	Φ610X28 thk	
80-8	Φ406x15.9 thk	H5	1.006	Φ610X28 thk	
81-82	Φ168X9.5 thk	H51	1.420	Φ219X12.7 thk	
82-7	Φ406x15.9 thk	H5	1.726	Φ610X28 thk	
129-7	Φ508X28 thk	B5	1.021	Φ610X25 thk	Actual propesed size was Φ610X20 thk but cross sectional area of Φ610X20 was less than actual member, Φ508X28 so Φ610X25 thk is proposed.

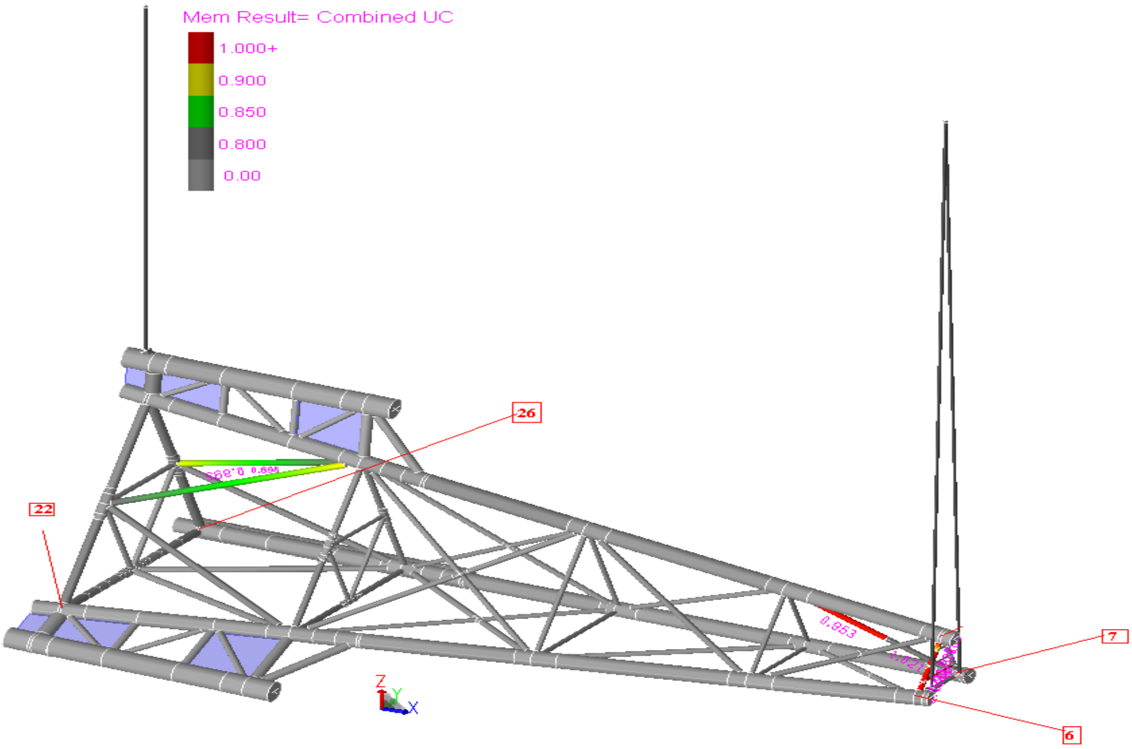


Figure 5 Tripod -UC Failure members & joints during Lift (By SACS 3D model viewer)

CONCLUSIONS

Lift, Load-out and Transportation analysis has been done on Tripod structure with original members and later Tripod has also checked with revised member sizes and with revised member sizes no member failure is found. Structural safety has been checked during different analysis by applying several Load combinations. Structure is checked for member strength in bending, direct forces and combined stresses. Structural failure has been shown for different analysis in tabular form and solution of failures has been also shown. For joint failures in Punching some inter ring stiffeners has suggested. The structure is found more critical during Lift and least critical during Load-out.

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REFERENCES

[1] API-RP 2A, "Recommended Practice for Planning, Designing & Constructing Fixed Offshore Platforms (WSD)", 21st Edition.
[2] AISC, "Manual of Steel Construction" Allowable Stress Design 13th Edition
[3] SACS (Structural Analysis Computer System) Release 5.3
[4] Handbook of offshore engineering subrata k. chakrabarti
[5] Handbook of offshore engineering Angus mather
[6] Octa Engineers (2003), Technical Notes for Structural Design of Offshore Topsides and Jackets
[7] Dynamics of Fixed Marine Structures – Barltrop N.D.P, Adams A. J, 3rd Edn.
[8] NPP2 Jacket Analysis Report – Report 6-21 (Ocean Engineering Group)

AUTHOR BIBLIOGRAPHY

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