ISSN 2278 – 0211 (Online)

Study on the Failures of Leg Lattice Structure When Offshore Drill Rigs Are Being Converted from Mobile Offshore Drilling Units (MODU) to Mobile Offshore Production Units (MOPU)

Bh. Nagesh
Research Scholar, Department of Marine Engineering, Andhra University, Visakhapatnam, India
I. N. Niranjan Kumar
Professor, Department of Marine Engineering, Andhra University, Visakhapatnam, India
Dr. Manu Korulla
Scientist, G. Naval Science and Technological Laboratory, Visakhapatnam, India

Abstract:
The Rig Owners intend to convert the age old offshore drilling rigs which are basically designed for drilling of oil and gas (called as Mobile Offshore Drilling Unit - MODU) into Mobile Offshore Production Units (MOPUs). While doing so, the important element to be noticed is the air gap between the water line to the bottom of hull vis-à-vis the operating depth at site specific conditions. The air gap which normally increases compared to when the same has been used as a MODU, due to the reason that it is a fixed platform and regular jacking operations cannot be performed whereasrules call for the supporting structure to withstand the 100 years of wave and wind data in which case the wave height can be expected upto 14m and wind speeds upto 100 knots, the bottom of hull should be elevated to a height of at least 1.5m more than the highest wave that can occur including the surge, swell etc. In such a conversion the important parameter that is being missed out is the lack of leg strength that will not be able to n withstand the 100 years wave and wind criteria. This paper shows the study conducted on the failure of leg lattice structure of the Jack-up Rig Legs by conducting the Global Strength Analysis.
The Finite Element Method is used to determine the stresses and strains in various joint sections of the leg lattice by modelling the entire rig structure in SACS modelling and FE analysis software which is extensively used in offshore industry. The analysis have been done on the leg structure of a three legged drill rig with spud cans which has been undergoing conversion process from Mobile Offshore Drilling Unit (MODU) to Mobile Offshore Production Unit (MOPU) for installation at Mumbai High. The failure analyses have been done for two different locations of installations with different water depths and soil conditions with 25 years wind data, 50 years wind data and 100 years wind data at the site specific conditions.

Keywords: *Jack up rig, mobile offshore drilling unit (MODU), mobile offshore production unit (MOPU), stress, displacement, chord pipes, bracing pipes, leg penetration, air gap, wave theory.*

1. Introduction

Conversion of a Jack-up drilling rigs called as Mobile Offshore Drilling Units (MODU) to production units technically called as Mobile offshore Production Units (MOPU) is a product of the development of marginal fields. For more and more applications, oil companies are considering the use of mobile offshore production units (MOPUs), especially Jack-ups, instead of conventional platforms. Construction of entirely new platform costs more and can be spread over several fields, making the conversion option as more attractive. Following economic considerations usually come into play in making such a decision.

- Less time to convert rig than build platform
- It is less costly to convert a rig than to build a new platform entirely.
- Ideal for approaching lease expiration date
- Accelerate schedule to first production
- Ease of relocation when risks are high
- Reduced up-front capital costs
- Lower abandonment costs
- Facility can be released when product prices fall
- Conversion requires dock space, not yard space

With the above economic considerations this conversion option is the best in industry for oil companies. However, important checks are also essential while conversion or else the failures of several kinds are happening. One of the important failure cases is the failure of the leg lattice structure after conversion and installation of the MOPU at site during severe weather conditions which necessitates the downtime of production and rework in the dry-dock/shipyard which causes both loss of revenue and additional costs for repairs and refits.
The rig under study in this paper has been built in 1972 and has performed as drilling rig in various locations in the past. Presently the rig has been decided to be converted into Mobile Offshore Platform Unit (MOPU).

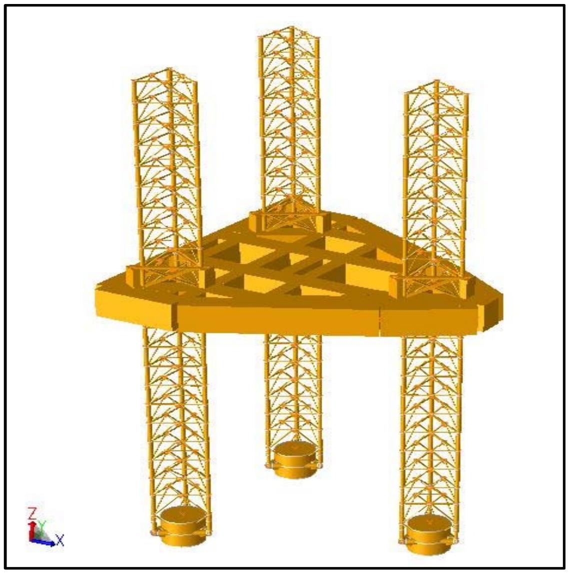


Figure 1: Three Dimensional FE Model of the Rig

A lattice structure assembled with tubular members is adopted for the leg structure in the deep waters for reducing the wave forces and current forces on structure to a minimum, whereas a pure cylindrical pipe structure may be considered for areas with comparatively shallow water depth. The triangular column lattice structure mentioned above for a jack up rig consists of 3 chords, horizontal braces and six diagonal braces. The leg strength of this structure is investigated here for installation at site-specific conditions.

1.1. Scope of Work
The rig under study is a three legged jack-up unit, each leg has three chords truss framed with bracings all being tubular members. The scope of work for the present study is to carry out following;

- To verify that the structure reliably supports the total elevated load in a specified environment for storm conditions throughout its life cycle.
- To evaluate the leg strength considering all relevant, realistic load conditions and combinations.

To achieve the above tasks, the extreme wave analysis with dynamic effects included for Jack-up Rig have been carried out in the Structural Analysis Software, SACS 5.6.

2. Approach to the Problem
During conversion of Rig from MODU to MOPU the weights of all items that have been removed and new weights added to convert it as process platform have been considered and the final weight is found to be higher than the original weight of the Rig. By using simple methods which have been formulated in the past with mathematical equations and empirical relation (Ref#1), the member stress calculations have been performed by applying these empirical relations. Through manual mathematical calculations it has been observed that the structural failures of some of the members of the leg lattice in way of the leg-hull interface areas have been noticed.For validation of the calculation results of stress calculations of leg structures, and to identify the underlying problem of structural failures, a Finite Element (FE) model has been generated inSACS software to analyse the leg lattice structures using "finite element techniques". The site specific geotechnical investigations have been carried out in accordance with SNAME TR 5-5A (Ref#2). For Stress calculations, guidelines given in API RP-2A WSD (Ref#3), Recommended practice for planning, designing and constructing fixed offshore platform – Working Stress Design, 21st edition, supplement 1-3, have been followed. All important calculations have been discussed in Section 7 of this technical paper. Figure 1 below shows the 3D model developed for FE analysis.

2.1. Specifications for Analysis
Table 1 below shows the specifications given for carrying out the Rig Elevated Analysis.

Elevated lightship	5617 tons
Variable weight	1250 tons
Leg Self weight	2190 tons
ENVIRONMENTAL CONDITIONS:	
Water depth	50 m
Wind Speed	191.88 km/hr (103.6 knots)
Wave Height	13.42 m
Wave Period	12.00 sec
Spud can penetration	3.75 m
Current speed varies with height as below.	
0.00 m	0.0 m/s
47.0 m	0.257 m/s
50.0 m	0.514 s

Table 1: Specifications for Analysis

2.2. Leg Reserve Length Estimation

Table 2 below shows the leg reserve length calculation. Refer Figure 2 below showing the diagrammatic representative of the Jack-Up Rig in elevated condition.

Total leg length	124.00 m
Penetration	3.75 m
Water Depth	50 m
Wave Crest Elevation	9.24 m
Air gap	3.275 m
Hull depth	7.0 m
Jack house height	5.084 m
Leg Reserve Length	45.651m

Table 2: Leg Reserve Length Estimation

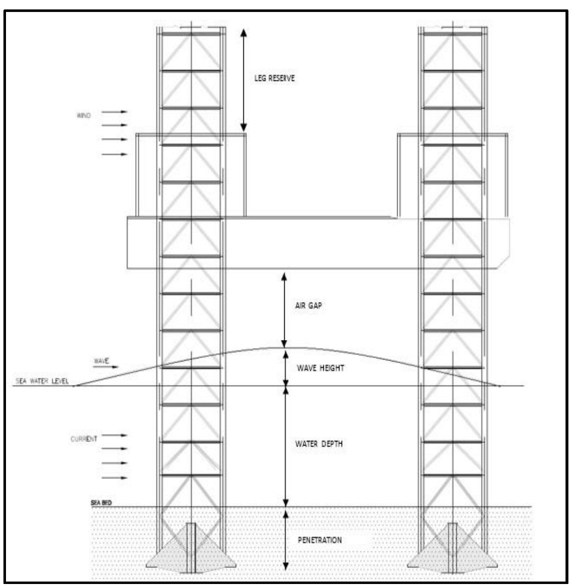


Figure 2: Diagram indicating the Jack up Rig in elevated condition

3. Overall Methodology

The objective of the analysis is to verify that structural reliable supports the total elevated load in a specified environment for storm conditions throughout its life cycle. The leg strength has been evaluated considering all relevant, realistic load conditions and combinations.

There are two conditions of the rig for which the leg structure should be investigated. (i) The condition where the leg is grounded to the sea bed and the towing condition. For the towing mode, the leg is lifted up to the free surface (Ref#4). In the former case, the structure is subjected to the fluid forces due to waves, currents and winds, and loads due to the platform, leg weight and loaded weights. In the towing mode case, the structure is subjected to inertial forces due to the motion of the platform as a floating body and the self-weight of the leg. Both the cases need structural strength analysis problems of the triangular column lattice structure those are subject to forces in the transverse direction and axial direction.

ABS Guidance Notes for Dynamic Analysis of Self elevating Drilling Units(Ref#5) have been used for defining the boundary conditions and load cases. The mathematical calculations have been verified by using the structural FE model analysis. A high degree of accuracy in the analytical method has been used.To investigate its validity and verify the accuracy, due to the structure complexity, certain conventions have been adopted in constructing the actual structure of legs for global analysis, as given in some examples in technical papers (Ref#6,7). The results are compared with the results of "Detailed structural analysis" of a lattice structure using the general purpose structural analysis program, SACS.

3.1. Boundary & Load Conditions

Leg is assumed to be pinned 3.75m below the sea bed (based on leg penetration analysis) which brings more realistic behavior of the legs under the action of environmental and elevated loads. Sequence of fixity input on each joint is shown below is F_x, F_y, F_z, M_x, M_y, M_z. The Figure 2 below shows the boundary condition for the model.

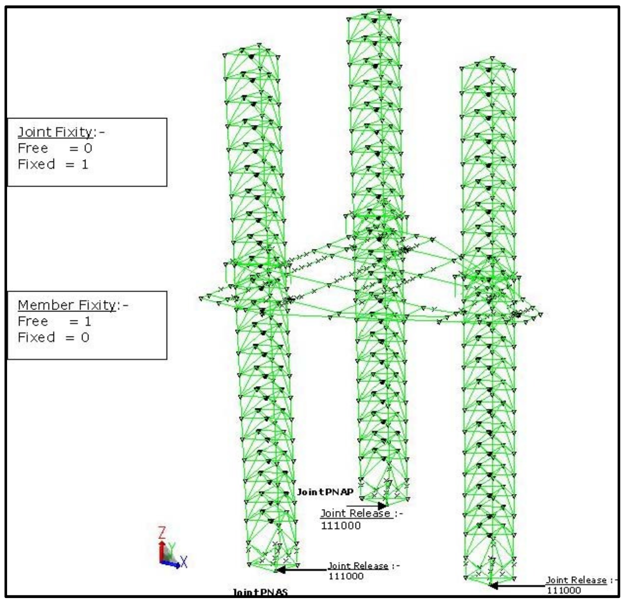


Figure 3: Boundary and Load Conditions

3.2. Leg Hull Interface

Leg is connected to hull via clamping mechanism (fixation system) during operating condition. Entire elevated load is transferred from hull to leg via clamping mechanism as shown in the Figure 4 below.

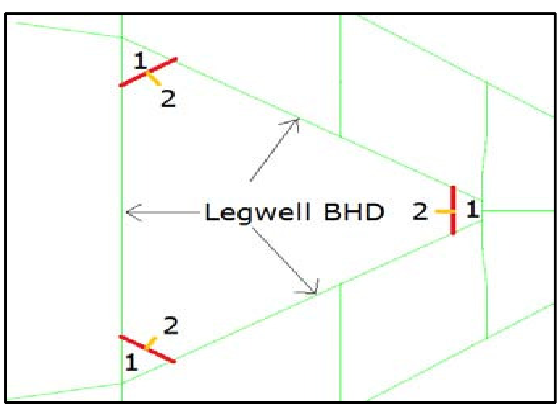


Figure 4: Leg-Hull Interface Details

Clamping mechanism is modelled as beams (no.1) connected between leg and leg well. For correct behavior of interface, axial and bending stiffness of clamping mechanism is calculated and beams are modeled with properties of equivalent stiffness as that of clamping mechanism.Racks on chords do not pass through centerline of chord and has 300mm offset from chord centerline. This offset is modeled with help of beams connecting chord and clamp mechanism (no.2) with equivalent properties of leg cross section of 200 cm x 90 cm is used to model these beams.

3.3. Gap Elements

Clamping mechanism consists of rack-type positive locking system having two sets per chord on either side. Due to virtue of clamping mechanism geometry and arrangement, for axial load, it is effective only in compression. To simulate this behaviour, these beams are modelled as gap elements (only compression elements).

4. Loading Combination

Environmental loads such as wind, wave and current is applied on structure in respective direction. Figure 5 below shows typical environmental load application scenario. P-delta loads have been included in analysis using respective load cases. Elevated load, variable load, buoyancy load and leg weight are considered as P-delta load cases. Inertial loads due to dynamic action of waves are considered along with environmental loads.

Loading Combination has been considered for wind angles of 0^0, 30^0, 65.56^0, 90^0, 144.44^0, 150^0, 180^0have been considered in storm condition. All load combinations are similar as mentioned below:

Load combination = LTSH (Elevated Lightship) + VRIA (Variable Load) + LEG (Leg Self Weight) + ENVR (Wave, Current and Wind Load) + INERTIA (Dynamic loads) + PDELTA + BUOY (Buoyancy Load).(Ref#8)

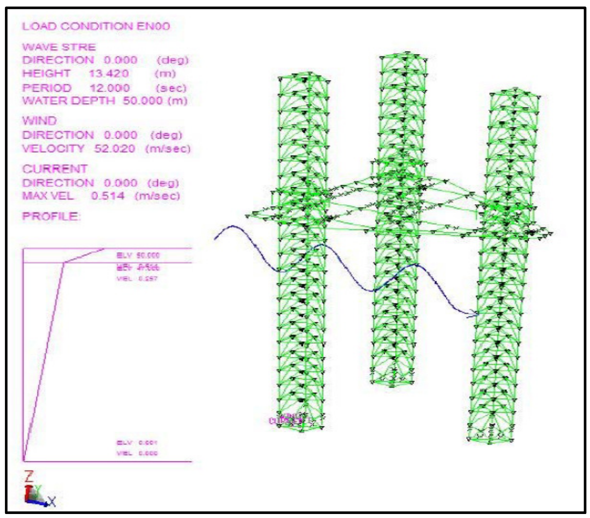


Figure 5: Environmental Load application scenario

4.1. Acceptance Criteria

As the analysis is carried out for storm condition with all the loads applied at a time, 1/3rd increase inallowable is considered in analysis.The acceptance criteria for all the member stresses, is as given in the Table 3 below.

Sections (leg)	Yield Stress (t/cm^2)	Factor of Safety	Allowable Normal Stress	Max.UC Value
Chord,Rack	7.00	1.25	5.40	1.00
Horizontal Brace	4.50	1.25	3.60	1.00
Diagonal Brace	4.50	1.25	3.60	1.00
Internal Brace	2.40	1.25	1.92	1.00

Table 3: Acceptance criteria for member stresses

5. Material Selection

While material selection we have to consider all types of design load and working condition. For Leg Lattice Tubular members, the consideration parameters are higher strength/density ratio, less corrosive in sea water, high yield stress of material. After defining the FE Model in SACS software, the meshing taking place after defining the geometry, viz., the point and the curves. After the geometry definition, the material characteristics are defined for the ABS Grade AH36 steels.

5.1. Material Properties of ABS AB/AH36 (High Strength Steel)

- Young's Modulus (E) : $2.1x10^{11}$ N/m^2
- Poison's Ratio (n) : 0.3
- Yield Stress(σ_y) : 380 MPa

- Density (ρ) : 7850 kg /m^3

5.2. Material Properties of ABS AB/DQ70 (Extra high strength steel).

- Young's Modulus (E) : 2.1×10^{11} N/m^2
- Poison's Ratio(n) : 0.3
- Yield Stress(σ_y) : 690MPa
- Density(ρ) : 7850 kg /m^3

The structure soil relation consists in the prohibition of movement in nodes 1,2 and 3 on the directions x,y,z and the circles around these axes, thus resulting in restraints.

6. Governing Equations

6.1. Wave and Current Forces Acting on Leg Structures

Morrison's formula (1950) is used here to derive the wave and current forces on tubular members of leg structures in sea water and wind forces above the water level. The hydrodynamic forces are calculated here on the basis of quasi-static assumption and only the horizontal forces are considered for the wave direction in each horizontal level of leg structures assuming the current direction is identical to the wave one.

In the detailed calculations of the hydrodynamic forces, the acting forces due to the particle motion of wave and current are given on each tubular member of leg structures such as chords, horizontal braces.

6.2. Selection of Wave Theory

Wave theory selection for particular location depends on water depth, wave height and time period associated with same. For present location, depend on above parameter, stream function theory of 5th order is selected. Refer Figure 6 below.

Wave Height	=	13.416 m
T_{ass}	=	12.0 sec
Water Depth	=	50.0 m
H/gT^2	=	0.0095
D/gT^2	=	0.0354

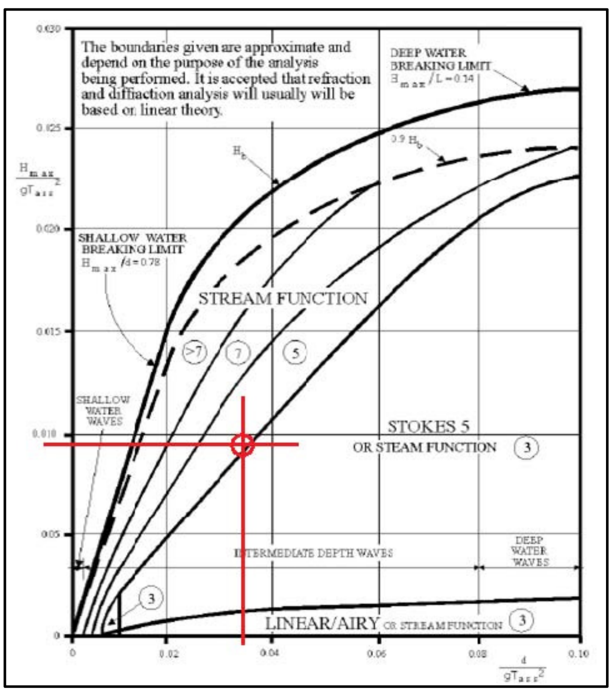


Figure 6: Stream Function Wave Theory

6.3. Added Mass Calculation

SACS Program has capability to calculate and consider added mass of water. Added mass coefficient of 0.8 [Ca = (Cm -1) = (1.8-1.0) = 0.8] is used for added mass computation. Consistent Mass approach is used for the mass distribution in model. All the members are considered to be buoyant except spud can which is assumed to be non-buoyant.To create mass model, SACS load cases containing the elevated loads, self-weight, etc. are converted into mass load cases. Non-linear P-delta effect is accounted into analysis by assigning specific loads case as P-delta load cases.

7. Details of Design & Analysis

Time varying nature of wave loads amplifies the static response of structure. To account the dynamic effect due to time varying wave loads, dynamic analysis has been carried out. Initially Eigen value analysis has been carried out to find out different mode shapes, model internal loads and stress vectors. These results are imported into extreme wave analysis to amplify the static response of structure.

7.1. Preliminary Design Calculations

The preliminary design calculations for member stresses have been carried out using the governing equations.

7.1.1. Spud Can Modelling

Spud can of this rig is conical in shape. To account for its correct area and volume for drag and inertia force calculations, it is modeled as equivalent cylinder having projected area and volume equal to actual spud can. Assuming triangular shape, the projected area of spud can = 0.5 x 7.0 x 15m^2 = 52.5 m^2

Volume of spud can (assuming conical volume) = 1/3 x PI x $(15/2)^2$ = 412.4 m^3.

Equivalent cylinder diameter = 8.70m

Projected area = 8.7m x 7.0m = 60.9 m^2

Inscribed Volume = PI/4 x 8.70^2 x 7.0 = 416.2 m^2

Spud can is assumed to be non-buoyant for buoyancy force compilation (Ref#9).

7.1.2. Marine Growth

Leg region from 6m above mean water line (MWL) to mud line is assumed to be rough (fouled) for the appropriate drag and inertial coefficient. Remaining leg region is assumed to be smooth. As such the marine growth is considered as “zero” in general due to the reason that owners/operators will maintain the rig well for next five years with proper Marine Growth Prevention System (MGPS) and anodes calculated and fixed for next seven and half years. During next operational site change, the anodes and MGPS will be changed to cater to next period of operation.

7.1.3. Chord Properties Calculations

Table 4, below shows the chord properties calculation with rack width considered effective for cross section area and moment of inertia calculation.

Group	Chord Diameter (cm)	Chord Thk (cm)	Rack Thk (cm)	Rack Width (cm)	Ax (cm2)	Ay (cm2)	Az (cm2)	Ix, (cm^4)	Iy (cm4)	Iz(cm4)
C30, C40, CF0	90.00	3.40	12.70	9.00	1154	615	615	1.74E+06	1.04E+06	1.20E+06
C31, C41, CF1	90.00	3.20	12.70	9.00	1101	589	589	1.65E+06	9.89E+05	1.15E+06
C32, C42, CF2	90.00	3.10	12.70	9.00	1075	576	576	1.60E+06	9.65E+05	1.13E+06
C34, C44, CF4	90.00	3.00	12.70	9.00	1049	562	562	1.56E+06	9.41E+05	1.11E+06

Table 4: Chord Properties Calculation

7.1.4. Jack House Properties Calculations

7.1.4.1. Jacking Foundation

For jacking foundation properties, highlighted section shown below (Figure 7) has been considered for cross section property calculations. Table 5 below shows the cross section properties considered in the analysis.

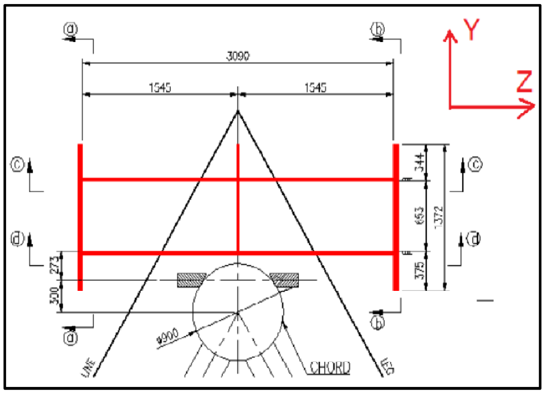


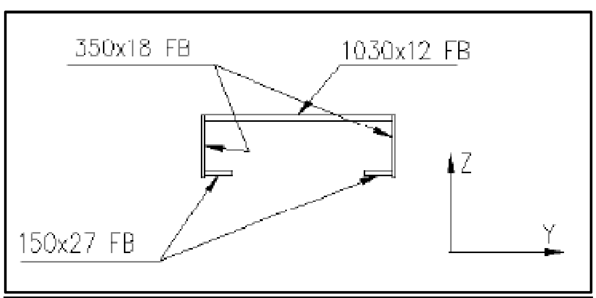
Figure 7: Jacking Foundation Details

Length	Z	319	cm
Breadth	Y	137.2	cm
C/S Area		3554.2	cm^2
Centroid	Z1	159.5	cm
	Z2	159.5	cm
	Y1	66.65	cm
	Y2	70.55	cm
Moment of Inertia	Z	2.05E+07	cm^4
	Y	1.39E+08	cm^4
	X	6.12E+06	cm^4
Section Modulus	Z	2.90E+05	cm^3
	Y	8.73E+05	cm^3
Shear Area	Z	2009.7	cm^2
	Y	1630.8	cm^2

Table 5: Jacking System cross section calculations

0.514.1.1 Jack-house Top Beams

Figure 8Below shows the section & properties considered for the jack house top beams calculation.



A_x	A_y	A_z	I_x	I_y	I_z
cm^2	cm^2	cm^2	cm^4	cm^4	cm^4
330.60	127.92	84.00	392.24	63150.33	607257.64

Figure 8: Jack-House top beam section details

0.514.1.2 Jack-house bracings:

Bracing of I-beam cross section of 1030 x 16, 350 x 25 cm dimensions have beentaken in calculation.

7.2. Hydrodynamics

7.2.1. Drag & Inertia Coefficients

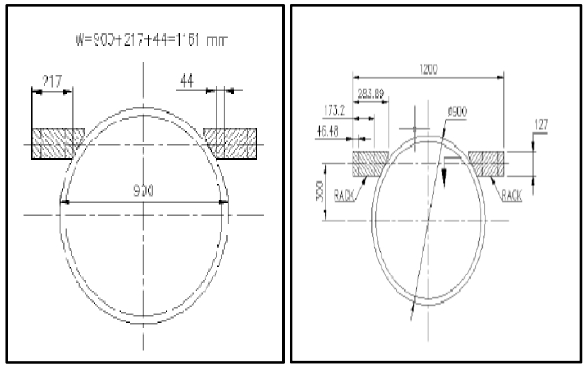


Figure 9: Chord Dimensions with Rack attached

Morrison's equation is applicable for calculating hydrodynamic wave loads on this Jack-up Rig because the diameter of the chord is less than 20% of wavelength of design wave. For all the directions as mentioned in para 4, the drag coefficient is calculated numerically by determining the equivalent drag coefficient for complex geometrical shape of chord.

The Figure 9 above shows the Chord dimensions with Rack attached. The drag and inertia coefficient values calculated for chords in different heading angle is shown in Table 6 below.

Element	**Heading angle * (deg)**	**Smooth Cylinder**		**Rough (Fouled) Cylinder**	
		C_d	C_m	C_d	C_m
Chord	0	0.65	2.00	1.00	1.80
Chord	24.45	0.67	2.00	1.01	1.80
Chord	30	0.73	2.00	1.07	1.80
Chord	35.55	0.85	2.00	1.16	1.80
Chord	60	1.69	2.00	1.83	1.80
Chord	85.55	2.34	2.00	2.35	1.80
Chord	90	2.36	2.00	2.36	1.80
Braces	All	0.65	2.00	1.00	1.80

Table 6: Drag & Inertia coefficient for various heading angles
"" heading angle refers to angle made by wave direction with rack plane*

7.2.2. Current Blockage Coefficient

The calculation shown in Table 7 below shows the estimation of current blockage parameter. Based on this calculation, a value of 0.88 has been considered as current blockage coefficient in the analysis.

Direction (deg)	**D_e (cm)**	**C_{de}**	**D_1 (cm)**	**Current Blockage parameter**
0	192.67	3.36	1183.0	0.88
30	192.67	3.46	1033.1	0.86
65.56	192.67	3.38	1177.4	0.88
90	192.67	3.46	1033.1	0.86
114.44	192.67	3.38	1177.4	0.88
150	192.67	3.46	1033.1	0.86
180	192.67	3.36	1183.0	0.88

Table 7: Current Blockage Coefficient

7.2.3. Snap shots of Model

Below pictures (Figure 10 to 14) show snapshots from the model taken to indicate the different mode shapes of Jack up in elevated mode. Mainly firstthree modes (surge, sway, and yaw) are shows below.

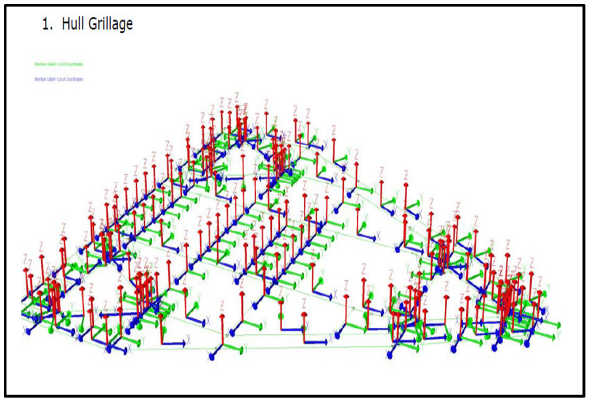


Figure 10: Hull Grillage for Local Axis

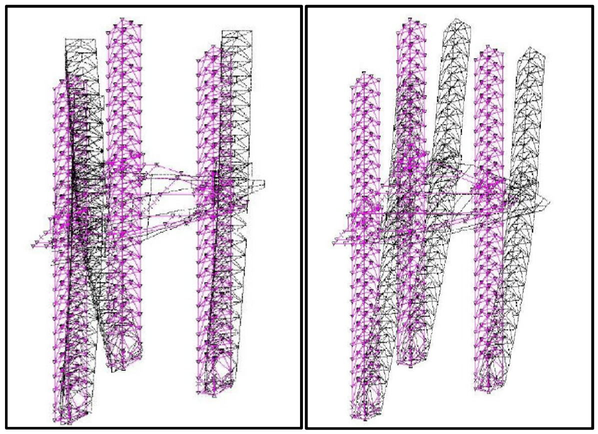


Figure 11: Mode Shapes of Jackup in elevated mode.

8. Summary of Results

According to a report by MSL Engineering Limited prepared for Health and Safety Executive, it has been revealed that 53% of the failures that jack-up rigs experiences is due to punch through of the legs. Other causes include uneven seabed, volcanic activities, unexpected penetration of the legs, sliding of mat foundation and mudslide etc. (Ref#10,11)

In the present case, through FE analysis it has been noticed that the cracks may be developed in some tubular members where stress concentration factors are found to be high. These locations have been discussed in the conclusions.In high cycle fatigue situations, materials performance is normally characterized by the S-N Curve. The graph depicts of a cyclical stress (S) against cycles of failures (N). Failure due to repeated loading is called fatigue.Fatigue failures are often caused by the degradation of metal surface. A rough surface finish, a scratch or oxidation will provide an initial crack. Cracks will propagate after cyclical loading and eventually lead to fatigue failure.

8.1. Summary of Frequencies

Summary of model frequencies and natural time period for 30 modes for elevated condition are shown in Table 8 below.

Mode	Freq. (cps)	Period (sec)	Mode	Freq. (cps)	Period (sec)
1	0.178	5.623	16	2.514	0.398
2	0.181	5.539	17	2.612	0.383
3	0.208	4.818	18	2.618	0.382
4	1.193	0.838	19	2.667	0.375
5	1.248	0.801	20	2.766	0.362
6	1.267	0.790	21	2.769	0.361
7	1.286	0.778	22	2.811	0.356
8	1.291	0.775	23	3.187	0.314
9	1.294	0.773	24	3.307	0.302
10	1.387	0.721	25	4.103	0.244
11	1.395	0.717	26	4.108	0.243
12	1.485	0.673	27	4.110	0.243

Mode	Freq. (cps)	Period (sec)	Mode	Freq. (cps)	Period (sec)
13	1.903	0.525	28	4.170	0.240
14	1.904	0.525	29	4.946	0.202
15	1.912	0.523	30	5.094	0.196

Table 8: Summary of model frequencies

8.2. Summary of Support Reactions

Joints	Load Conditions	Support Reactions		
		F_x(kN)	F_y(kN)	F_z(kN)
PNAP	C114	2696.65	-4884.82	56871.54
	C150	4240.09	-2889.08	50199.65
	C180	4245.35	-513.18	38144.65
	CB00	-3334.90	-130.83	17052.97
	CB30	-3073.45	-2387.82	30195.03
	CB65	-1009.13	-4591.00	46712.54
	CB90	992.31	-5050.61	53542.43
PNAS	C114	1366.65	-3699.76	8137.27
	C150	3703.47	-1757.28	25107.63
	C180	4208.08	566.00	38151.39
	CB00	-3272.71	115.21	17070.92
	CB30	-2924.11	-1889.17	5463.48
	CB65	-1710.78	-3454.35	-1113.92
	CB90	-471.13	-3751.13	1639.054
PNFW	C114	1583.44	-4063.72	19850.62
	C150	3428.44	-1780.94	9551.76
	C180	3435.08	-53.60	8536.08
	CB00	-5379.26	16.56	50774.38
	CB30	-5056.26	-2015.34	49252.30
	CB65	-2725.94	-4147.22	39374.95
	CB90	-534.11	-4661.79	29740.44

Table 9: Summary of Support Reactions

8.3. Summary of Deflections

Summary of maximum deflections for combined load cases w.r.t. global coordinate system are shown in Table 10 below.

Load Case	Joint	'X' Deflection (cm)	Joint	'Y' Deflection (cm)	Joint	'Z' Deflection (cm)
C114	PP22	-60.57	FF22	155.11	FP08	-10.71
C150	PP22	-115.17	FF22	76.79	HL06	-9.82
C180	PP22	-119.09	SF22	5.65	HL01	-9.58
CB00	PP22	134.63	SP22	2.09	FF28	-9.58
CB30	PS22	125.63	FF22	71.44	HL18	-11.69
CB65	SS22	72.18	FF22	147.99	HL18	-12.97
CB90	SS22	19.78	FF22	169.58	HL18	-11.73

Table 10: Summary of deflections

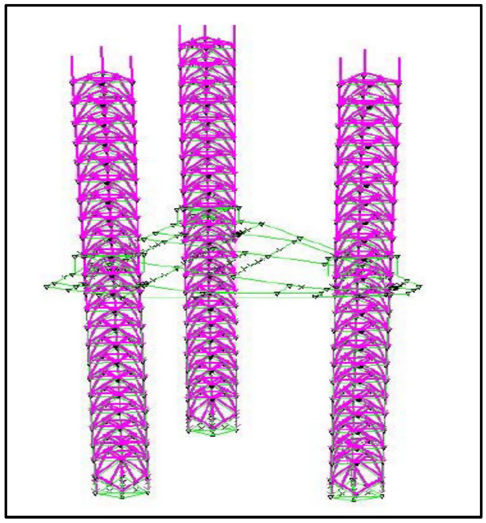


Figure 12: Picture showing the displacement scenario

8.4. Summary of Reaction i.w.o. Clamping Mechanism

Leg	Chord	Maximum force (kN)	Minimum force (kN)	Holding Capacity (ton)
Forward	Forward	20452	-30392	0 to -1400
	Port	25985	-34236	0 to -1400
	Starboard	12271	-45858	0 to -1400
Port	Forward	19788	-43778	0 to -1400
	Port	19554	-15884	0 to -1400
	Starboard	-983	-44334	0 to -1400
Starboard	Forward	22642	-39100	0 to -1400
	Port	26247	-17212	0 to -1400
	Starboard	5584	-29616	0 to -1400

Table 11: Summary of Reactions i.w.o. Clamping

8.5. Summary of Members and Joint UC

Member			Joint		
Load case	Actual UC	Allowable UC	Load case	Actual UC	Allowable UC
CB65	1.35	1.00	CB65	8.76	1.00

Table 12: Summary of Reactions i.w.o. Clamping

8.5.1. Additional Preload Capacity

The summary of static reactions, maximum reaction and required additional pre-load are shown in Table 13 below.

Leg	Joint	Static Leg Reaction (kN)	Max. Leg Reaction (kN)	Max preload capacity (Ton)	Additional preload required (ton)
Port	PNAP	27501	56272	3600	2136
Stbd	PNAS	27514	56872	3600	2136
Fwd	PNFW	29586	50774	3550	1626

Table 13: Additional Pre-Load Capacity Estimated

From the table above, it is seen that there is additional preload requirement of 5898 tons. So, increase in preload capacity is suggested.

9. Conclusions

Maximum UC Values from all leg members in SACS output is 1.35 for leg chord member, 1.45 for diagonal members and 1.13 for horizontal members.

At present all the calculations are done with zero marine growth with an aim that the owner organizations will maintain the marine growth prevention systems perfectly for next seven years of operation. However, if marine growth is also to be considered then the drag co-efficient values will increase which will lead in increased failure of structures.

As seen from summary of reactions in way of clamping mechanism, chord axial forces are exceeding above the holding capacity of clamping mechanism. The present clamping mechanism can hold the overall system in compression only whereas some loads are found to be tensile. So, present clamping mechanism is found to be unsatisfactory for the operation of Jack-up. To satisfy the holding capacity requirement, increased in holding capacity for clamping mechanism is suggested.

The analysis of the rig's own pulsations shows a decrease of the pulsations. It is an indication to the offshore rig's operator to avoid the overlap of the calculated pulsation to the pulsations of drilling machines.

The numerical analysis performed is useful in taking into account the various collision scenarios.

10. Acknowledgements

Authors are thankful to Pipavav Shipyard Limited Authors are also thankful to all the project membersinvolved in the Conversion project of the ONGC Rig 'Sagar Laxmi'.

11. Nomenclature

H [m]	Wave Height
D [m]	Water Depth
T [sec]	Wave Period
g [m/sec^2]	acceleration due to gravity
E [N/mm^2]	elastic modulus of the material

12. Greek Conventions

σ_y [N/mm^2] yield stress of the material.

ρ[kg/m^3] density of material

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