



Strength Check for Legs Structure of Jack-Up Platforms in Transit Condition

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Abstract. In transit condition, jack up rig is a type of floating structures with large dimensions. The leg structures of jack up rig are raised up during transit, therefore they are not directly subjected to wave and current loads, they just bear inertial forces due to system's shake caused by wave and current actions and other loads. To analyze strength of the leg structures of jack up rig in transit condition in accordance with current code and standards, it needs to solve two important problems which are to determine the jack up rig's motions and the inertial forces acting on leg structures due to the motion mentioned above. In this article, these issues will be clarified through an example of 400-foot jack-up rig which is fabricated in Vietnam.

Keywords: Leg structures of jack up rig · Transit condition
Strength checking

1 Introduction

Jack up rig is a type of mobile platform that operates in three states, including: transit, raised and lowered and operating condition. In transit condition, it is calculated as a Floating Offshore Unit, whereas, the leg structures are not directly subjected to wave and current loads. The effect of wave and current on the Jack-up rig structure in the transit condition is determined by the inertial force induced by the shaking of the system under the effect of wave and current (Fig. 1).

The purpose of article to verify methodology and algorithm to determine the effect on the leg structure of jack-up rig in transit condition to analyze and strength check.



Fig. 1. Jack up rig in transit condition

2 Shake-Motion Analysis of Jack up Rig and Determination of the Inertial Forces Acting on the Legs in Transit Condition

Figure 2 illustrates the basic shake-motion components, including: surge, heavy, sway, pitch, roll, yaw. The shake-motion equation of the jack up rig subjected to the wave and the current loads is written as follows:

$$(M + A)\ddot{U} + C\dot{U} + KU = F(t) \tag{1}$$

Where: M is mass matrix in global coordinate system [1, 2, 9]; A is added mass matrix; C is damping matrix; K is the stiffness matrix of the system; U, \dot{U}, \ddot{U} are the components of displacement, velocity and acceleration vectors of the system, respectively; $F(t)$ is the wave load vector acting on the hull structure, due to the large dimension effect, including the load components caused by the incoming wave and the diffraction wave, determined by the incoming and the diffraction wave potential function Φ^R , respectively.

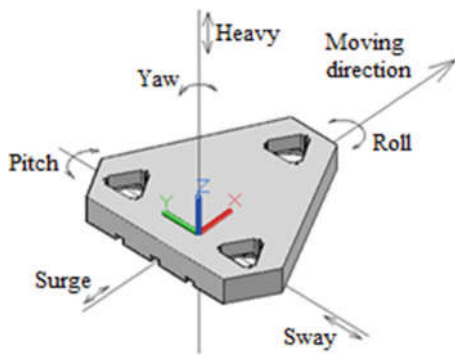


Fig. 2. Motions of jack-up rig

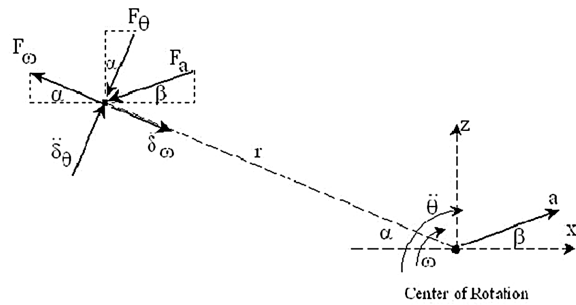


Fig. 3. Inertial forces in spherical coordinate system

The inertial force along axis x at the i^{th} mass setting point (m_i) on the leg structures, due to translational and rotational accelerations [1, 2]:

$$F_{ix} = -m_i \left(a_{ix} + r_i \ddot{\theta}_{ix} \sin \alpha + r_i \omega^2 \cos \alpha \right) \tag{2}$$

Where: a is the shaking acceleration of system center; θ_{ix} is the angle of inclination due to the shaking motion of the i^{th} mass around axis x (rad); r_i is the distance from the i^{th} mass to the center of system, α is the angles in Fig. 3. The inertial force along axis y is performed similarly.

3 Load Cases Analyses and Load Combinations to Analyze the Jack-up Rig Leg Structure in Transit Condition

In transit condition the load acting on the jack-up rig legs divides into two basic types. Static and quasi-static loads including: self-weight, technological loads and wind loads. The shaking motion induced inertial force components caused by the effect of waves and currents are presented in Sects. 2 and 3. The wind load F acting on a member of the leg structure can be calculated according to the API standard [4].

According to the current standards such as [3, 6] the load combinations for analyzing of floating structure in transit condition are considered in three main impact states as follows (these combinations are considered corresponding to the direction of the different motions):

- Head Sea: including roll, heavy, surge, wind and current respectively;
- Beam Sea: including pitch, yaw, sway, wind and current respectively;
- Quartering Sea: including 50% roll, 50% pitch and yaw, wind and current respectively.

Strength check of jack-up rig leg structure can be calculated according to the API standard [4] or AISC standard [9].

4 Algorithm Schema of the Problems to Be Solved to Calculate the Strength of the Legs of Jack up Rig in Transit Condition

The impact of the marine environmental factors on the Jack-up rig is assumed to cause two types of independent responses: the response of an absolutely rigid body under the shake-motion form with six degrees of freedom and the response of the elastic body in the form of stress and deformation of the structure. At the stage of the strength check and calculation of the jack-up rig leg structure in transit condition, the assumption of connections between the legs and the hull is pim-connected supports.

The general algorithm schema is described in Fig. 4.

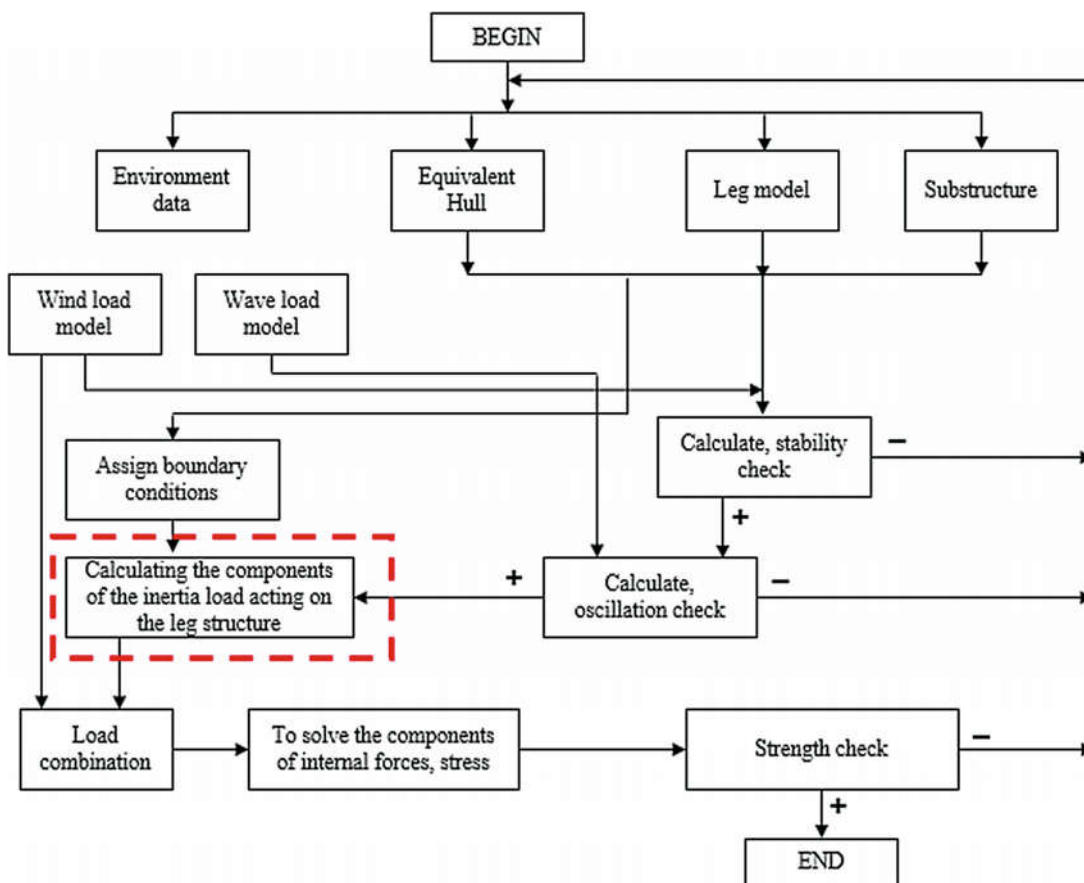


Fig. 4. The algorithm schema for strength check of jack-up rig leg structure in transit condition

5 Strength Check of the 400 ft Jack-up Rig Leg Structure in Transit Condition

5.1 Input Data

The scale of 400 ft jack-up rig structure: maximum length of Hull is 70.4 m; maximum width of Hull is 76 m; Height of Hull is 9.45 m; Number of Leg is three leg.

In the scope of the article, the environmental loads only calculated in NE direction with the following environment data: Wind speed: 36 m/s; Significant wave height H_s : 3 m; Wave period T_s : 6 s; Surface current velocity $V_{s-total}$: 0.57 m/s; Current velocity at 20 m depth $V_{20-total}$: 0.5 m/s; Mean current velocity $V_{m-total}$: 0.48 m/s; Bottom current velocity $V_{b-total}$: 0.43 m/s.

5.2 Modelling the Jack up Rig in Transit Condition by Finite Element Method

The 400 ft jack up rig structures are modeled by the finite element method as Fig. 5. Structural modeling, connection modeling, special structural modeling including: the chord and the rack are worked simultaneously and the boundary conditions to calculate the jack-up rig structure in transit condition is implemented in accordance to the DnV [5] and API [4].

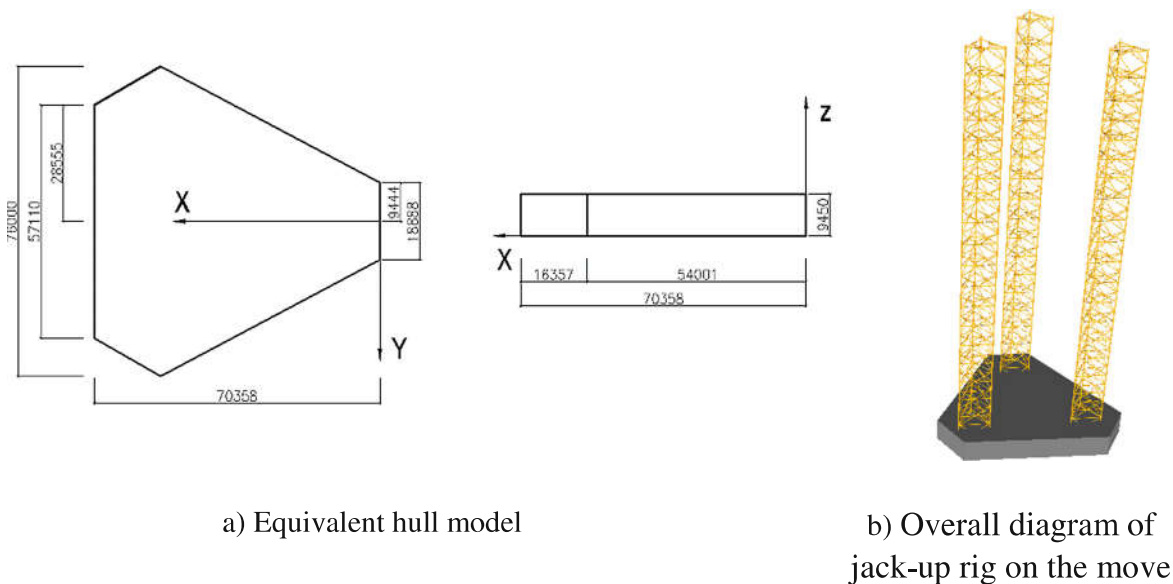
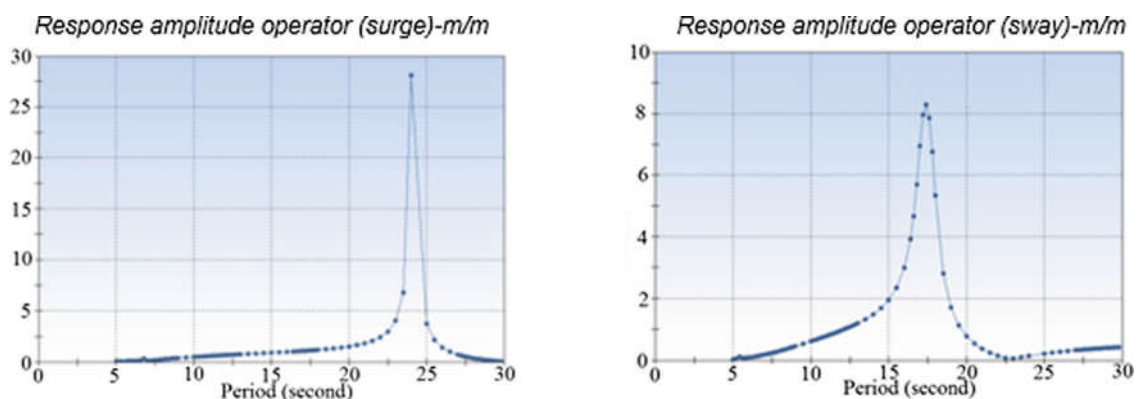


Fig. 5. Equivalent hull model and schematic diagram of jack-up rig

Load Combination: The inertial force due to the shaking motion of the system acting on the jack-up rig legs in transit condition is combined with other loads (self-weight, technology, wind load, etc.) to calculate and check the strength of the jack-up rig legs in transit condition. Case loads and load combinations are performed by Noble Denton [3] and DnV [6].

5.3 Results of Strength Check of the 400 ft Jack up Rig Legs in Transit Condition

Analyzing the shaking motion of the 400 ft jack up rig in the South Vietnam Sea was conducted by using specialized software program (SACS) [2]. Some representative results are shown in Fig. 6.



The biggest peak: 28.1 m/m, Period: T = 24s

The biggest peak: 8.3 m/m, Period: T = 17s

Fig. 6. RAO transfer function of the surge and sway motion of the 400 ft Jack up rig in transit condition

The acceleration of the system is determined by solving the motion Eq. (1). The product of the acceleration and mass gives us the inertial force. The results of the inertial force on the structural system of the 400 ft Jack up rig in transit condition, see Table 1.

Table 1. The results of the inertial force on the structural system of the 400 ft Jack up rig in transit condition

Load case	Angular accel			Trans accel/g			Force summation			Moment summation		
	Roll	Pitch	Yaw	Surge	Sway	Heavy	Surge	Sway	Heavy	Roll	Pitch	Yaw
	(Deg/sec ²)			(m/s ²)			(kN)			(kN.m)		
S11	0	-4.9	0	-0.22	0	-0.22	4477	0	20183	-540.7	1.15E6	119
S12	0	-4.9	0	-0.22	0	0.18	4477	0	6762	-181	1.15E6	119
S13	0	4.9	0	0.22	0	-0.22	-4477	0	-5171	138.3	-1.15E6	-119
S14	0	4.9	0	0.22	0	0.18	-4477	0	-18593	498.2	-1.15E6	-119
S15	-7.9	0	0	0	0.34	-0.26	0	-7019	8722	1.82E6	78.3	63
S16	-7.9	0	0	0	0.34	0.14	0	-7019	-4700	1.82E6	-42.2	63
S17	7.9	0	0	0	-0.34	-0.26	0	7019	8747	-1.82E6	78.5	-63
S18	7.9	0	0	0	-0.34	0.14	0	7019	-4675	-1.82E6	-42	-63

The inertial loads in Table 1 are the input data to calculate and check the leg of the 400 ft jack up rig in transit condition. Using SACS 5.3 software to solve the internal forces and stresses, which are combined with checking conditions in the standard [4] or [9] to get the results of strength check of the 400 ft jack-up rig legs in transit condition. Detailed are shown in Fig. 7.

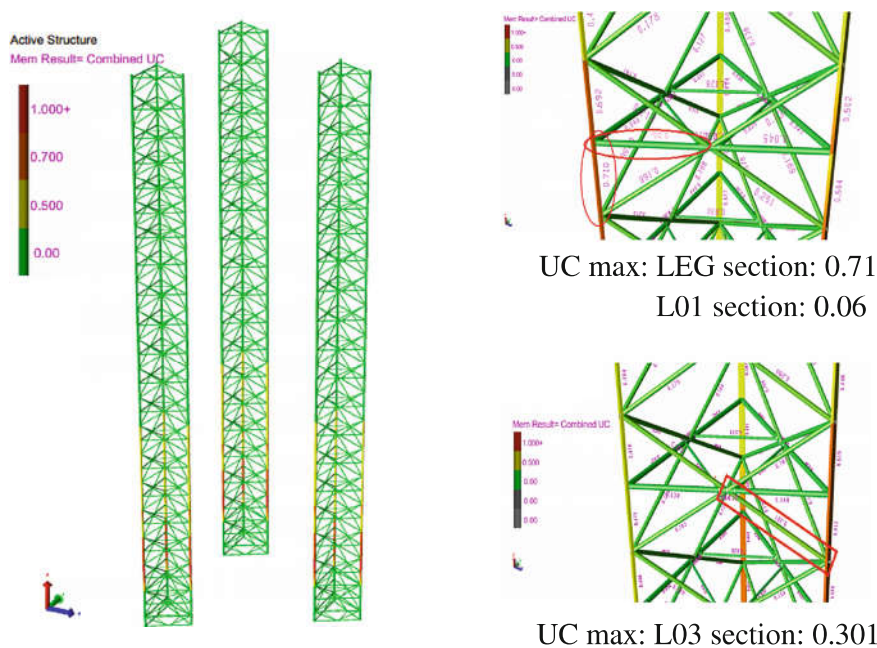


Fig. 7. Unity Check results of the 400 ft Jack up rig in transit condition

When checking the frame elements according to the API standard, the UC_{max} value = 0.71 (on the chord element) < 1 indicates that all elements of the leg are satisfied the strength conditions. The UC values are largest in the element which is located in the connection between the legs and the hull, and they are most dangerous. Strength check of the joints: The joints has the largest UC value = 0.504 < 1 , thus, they are satisfied the strength conditions.

6 Conclusion

This article gives a general algorithm to analyze and check the strength of jack up rig legs in transit condition.

The responses between large-sized floating objects with complex shapes and waves and currents are determined by the boundary element method, which are the basis for determining the inertial forces acting on the legs of the jack up rig when modeling independently the leg structure in the strength check.

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