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Innovative Methodology for Assembling Jack up Leg of 205m on ground of Ultra Harsh Jack up Rig

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Abstract

Generally, in jack up rig design for harsh environment, its leg height is a major factor for achieving a sufficient serviceability & operability in terms of the worst environment and the workable depth. Due to difficulties in constructing such a high-slender leg, inaccessibility of yard fabrication equipment, etc. the construction of Jack up rig for harsh deep sea has not been common. Method using heavy crawler crane, fabrication tower or extension by the floating crane vessel is still conventional construction but, considering high cost for mobilizing heavy lift vessel (HLV) or additional marine work for implementing preload / full height test at sea, the ground-base construction is much advantageous.
Air skidding method (ASM hereafter) is ground-based construction methodology, newly developed due to such requests. ASM could also be extended to similar engineering fields. This paper presents the operating sequence, design parameters and procedure which were verified through successful operation at the end of May 2002.

Key words: Jack up Rig, ASM (Air Skidding Method), Leg Assembly

1. Introduction

Jack up rig is normally constructed in dry docks. However, the construction of ultra jack up rig (for water depth more than 100m) needs additional works like leg extension. Recent days, there is a trend in designing the jack up rig capable of operating in harsh environment deeper waters by including all the critical issues and providing sufficient air gap, during the conceptual stage itself.
Jack up Rig explained in this paper was planned for water depth of 150m in the North Sea, ensuring the serviceability & operability under such a harsh environment. It is an independent 3-leg self-elevating Jack up with leg height of 205m.
For construction of 3 high-slender legs of 205m high, however, yard heavy lifting equipment like crawler cranes is found to be inadequate. Extension tower on yard or floating crane at sea was investigated as an alternative but, in practical, not found to be a cost effective solution for mobilizing extension tower or heavy lift vessel (HLV) for marine works. Hence a lot of investigations with respect to the cost, equipment delivery & construction schedule were carried out.
After various investigations, ASM, a new ground-based construction methodology of entire jack up rig leg, was selected. This method provides easy accessibility in construction and also allows to perform the major tests like full-height trial, preload tests in yard itself.

2. Overview of ASM

Jack up rig dealing with in the present paper is a self-elevating Jack up with XY cantilever drilling facility, hull depth of 12m, overall hull length of 110m and accommodation capacity of 120 persons (see Photo1). The legs are of 3-chord lattice type (chord-to-chord: 18m & leg height: 205m), which was designed to maintain sufficient flexibility against external environmental loads.

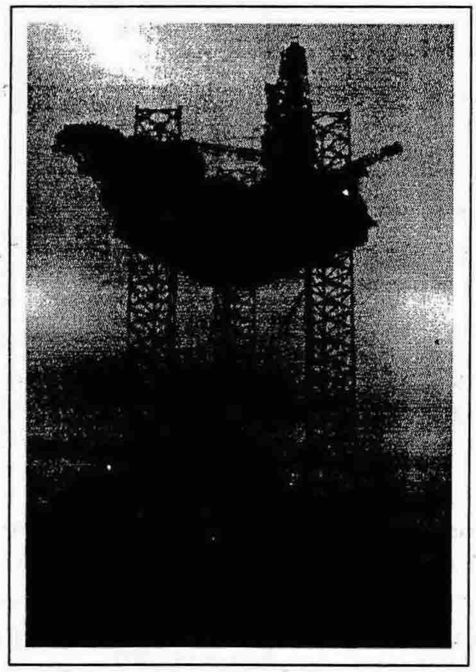


Photo1. Overview of APM Jack up Rig standing on ground

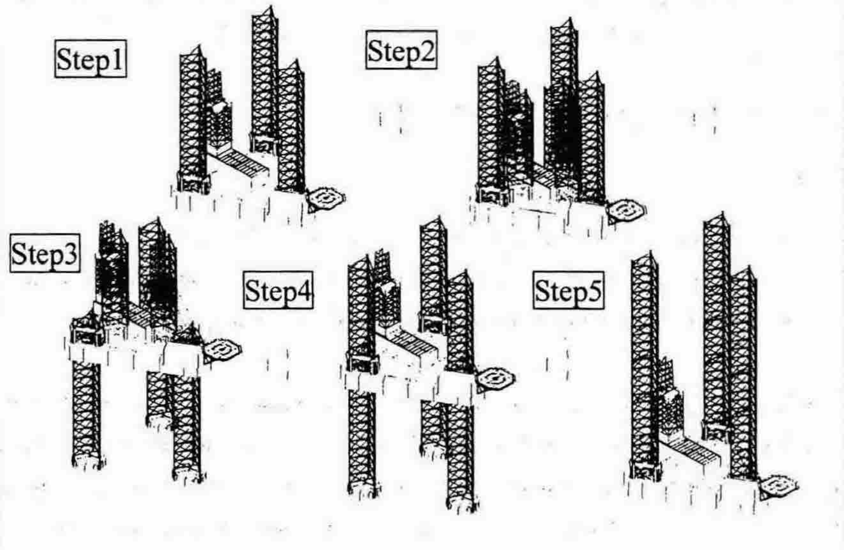


Fig.1 Overall sequence of air skidding method

Overall Sequence : Overall sequence of ASM is shown in Fig. 1. Due to the limitation of crane hook height available in yard, the legs were installed separately in two parts; lower & upper leg section. First, the lower leg section was assembled by heavy crawler cranes on ground and then placed within the leg well during the construction of hull construction (Step1 of Fig.1). Second the upper leg sections were placed on skid beams near to the lower leg sections (Step2 of Fig.1), after installing jacking and fixation system and verifying their operational functionalities. Skid beams, which play the role as supports and skidding path of each upper leg section, were suitably designed to take account of jacking house height above main deck. Then the hull was lifted up to the location where the tops of the lower leg sections become same in line with the bottom of upper leg section and fixation systems was engaged (Step3 of Fig.1). To ensure sufficient fixity at foundation, engineered sand pools were created before starting of all fabrication activities. And before hull lifting for ASM, pre-loading trial with above 2 times of jacking weight onto the engineered sand foundation was carried out. The Jack up lifting was carried out during the fine weather conditions. By means of strand-type pulling jacks each upper leg section was skidded slowly towards the lower leg section (Step4 of Fig.1). Once the upper leg section was reached exactly above the designated lower leg section, the upper leg section was lowered slowly by proper hydraulic jacks in order to achieve a gap (about 5mm between the tips) within the welding tolerance. Step5 of Fig.1 shows the final configuration of hull after completing leg assembly by ASM and lowering it to the load out position.

3. ASM Design Basis

Various parameters such as weight of upper leg section, wind velocity, inertial motion of rig, friction coefficient & stick-slip behavior were considered during development of ASM. Followings are the summary for such parameters.

Weight of upper leg section : Section height of 73m x 11ton/m = 805ton

Wind velocity : Since upper leg section(triangular-lattice-type with the distance of 18m chord-to-chord & 73m overall height) was to be skidded at 130m above ground, the wind & its influence on leg stability had become the most important factor for ASM design. Through sufficient evaluation of wind conditions over 10 years at yard, wind velocity for operation & design was determined as 13m/sec and 25m/sec respectively. Wind profile in accordance with DnV definition was considered. Wind force on rig structure as well as upper leg section was calculated using the equation given below. For designing all temporary systems of ASM and during the feasibility studies, the equivalent drag coefficient Cd for lattice-type leg section was calculated in accordance with SNAME rule and then compared with wind tunnel test. It had been found that both are in good agreement.

Inertial motion of rig : The elevated configuration of Jack up rig intends to move laterally with some period due to the force generated by wind. The periodic behavior, which leads to an inertial motion in each upper leg section, is mainly dependent on hull level elevated above ground and soil foundation fixity. Fundamental period of the unit is around 6.1sec for free fixity condition at spud-can. Taking into account of the amplitude of 0.2m, the horizontal acceleration of 0.2m/sec2 from this motion has been calculated, which causes additional inertia forces on upper leg section.

Friction coefficient & stick-slip behavior : To decrease friction coefficient during pulling of upper leg section by means of strand-type jacks, an engineered plastic on the skidding surface of skid way and SUS material on the bottom surface of skid shoe were installed. In addition, in order to reduce the friction further and increase the efficiency, silicon grease was spread on the skidding surface during skidding operation. The friction coefficient used for design is 15% for break out & 7% for moving condition. Since the difference in friction coefficient creates a stick-slip phenomenon, particularly for high-slander structure, which results in the inertial moment due to the different of working points. Since it generates some vertical loads onto skid structure as well as to the main hull at the start of pulling was expected, this phenomenon was taken into account at design stage.

4. ASM System Design

The major systems designed for air skidding operation along with the respective loads considered are presented here. Fig.2 shows overall configuration of ASM system at adjusting location.

Skid way & supports: Skid way & support was designed to sustain the leg at the skidding elevation of about 14m from main deck, in the configuration of bridge. The high concentrated load was evenly distributed into main bulkhead without overstressing through either large gusset or spreading frame.

Skid-gear assembly: Specification on Jack up rig generally does not permit welding work to the machine-treated rack. Hence the bolting mechanism for keeping the upper leg pieces in position during the operation was developed. Two (2) counter racks play the role of tightly grabbing each chord of upper section as shown in Fig.2.

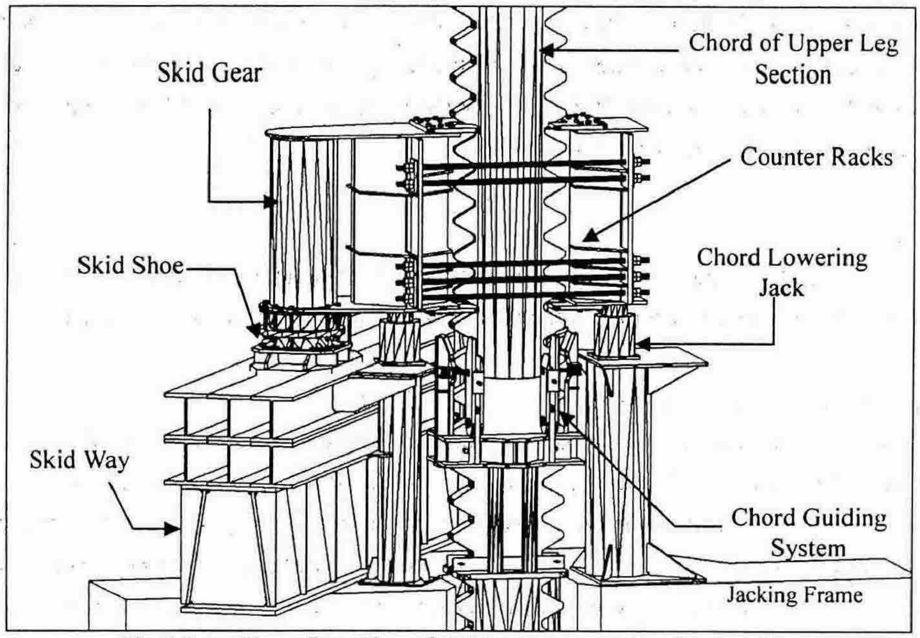
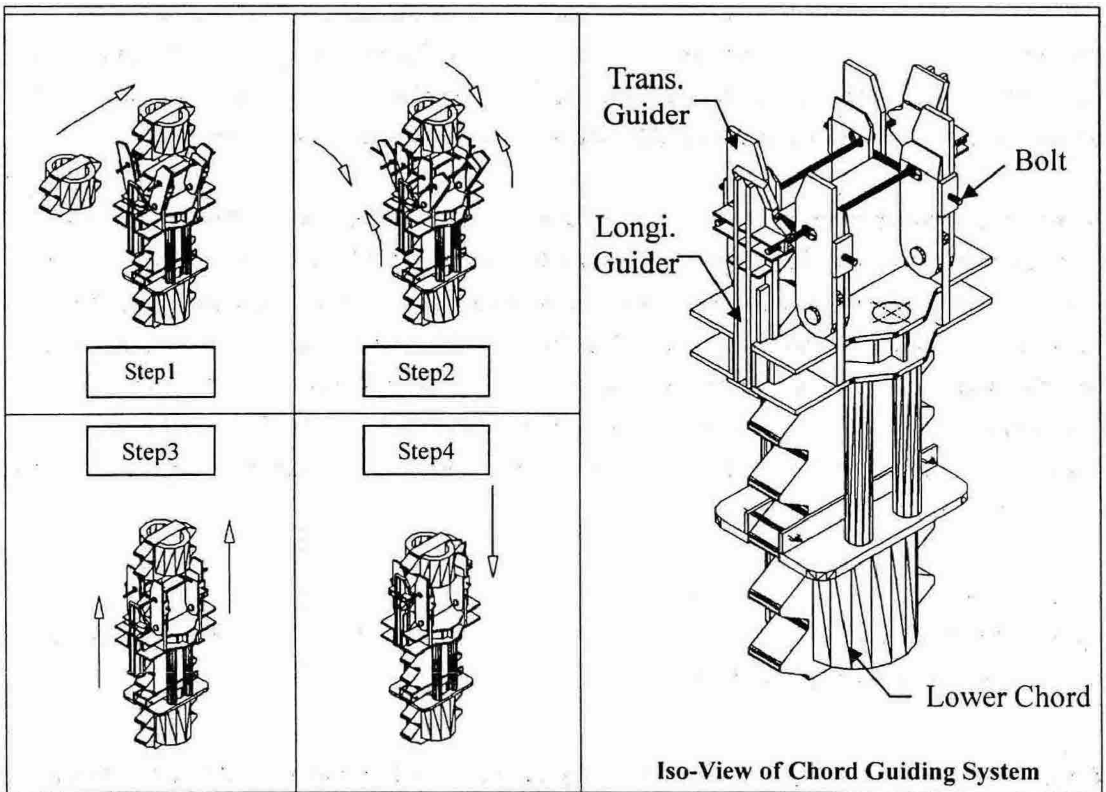


Fig.2 Overall configuration of ASM systems at adjusting location

Chord guiding system: To achieve a good workmanship in welding rack-to-rack and keep the fabrication tolerance within limits specified in design specification between rack tips, a chord guiding system was developed. Fig.3 shows the mechanism of chord guiding system with the sequence.



Step1 :	Pulling Upper Leg Section up to the adjusting position
Step2 :	Setting & tightening the trans. guider
Step3 :	Setting & tightening the longi. guider
Step4 :	Lowering & adjusting the upper & lower chords

Fig.3 Chord guiding system & mechanism explanation

Pulling system: Two (2) numbers of 105tons (S.W.L) strand-type jacks for pulling each upper leg section had been determined as adequate system in controlling & monitoring of lattice type structure having high slenderness.

5. Numerical Strength Evaluation

For the air skidding operation, the hull, leg structures and all temporary structures were verified against the loads mentioned above. The soil foundation at spud-can was also assessed with the previously collected soil data and boring test results.

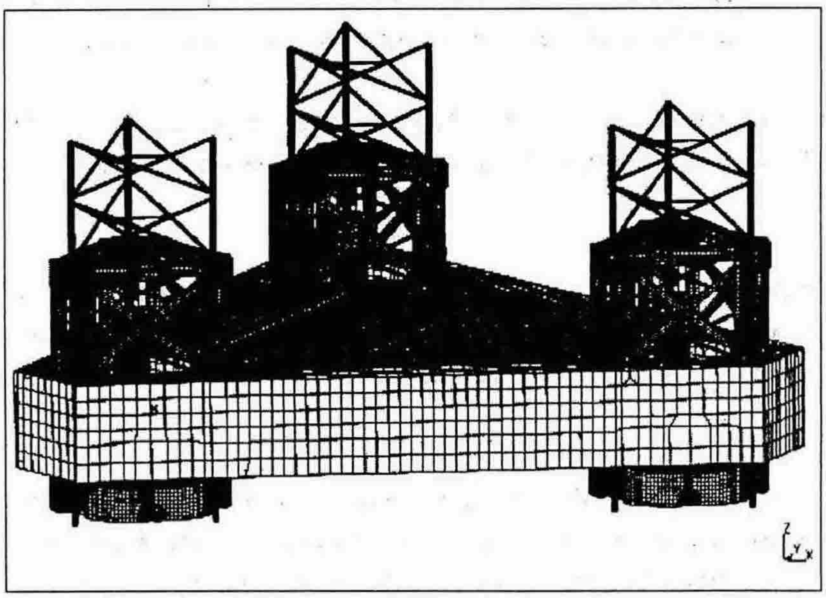


Fig.4 Overall View of FE Modeling for Hull Evaluation at Pre-load Trial

Hull strength evaluation : When the hull is elevated to the planned air skidding level, the rig would experience the various static / dynamic loads. Although the jack up rig has been designed for the much sever environment than ground-base construction, ASM was regarded as a special phase. The hull strength and foundation capacities were verified for preload trial case and air skidding case. Fig.4 shows the isometric configuration for FE analysis of Jack up rig at pre-load trial mode.

Leg strength evaluation: The hull strength and the lower leg section were evaluated for the lower and upper bound foundation fixity conditions such as free boundary (0deg soil internal friction) and partial fixity condition (27deg soil internal friction as estimated based on in-house soil data assessment) respectively. Since the legs are slender when the hull is elevated to ASM level, P-Δ effect representing the non-linearity of leg and more realistic K-factor for each brace were taken into account.

Temporary structure strength: Structural evaluation of all temporary structures was carried out using proper design parameters.

Soil foundation : For assuring the soil capacity, yard investigation on soil status had been carried out through proper boring & in-lab test. Lots of in-house soil data were collected from past projects. An engineered sand pool for each spud-can on yard was constructed to minimize the probability of error occurrence from the theoretical approach and keep up full contact with the spud-cans bottom. Moreover, by pre-loading the foundation with more than 2 times of to-be-lifted weight at ground level before air skidding, sufficient soil bearing was ensured. For engineering analyses of soil foundation, soil is considered as uniform and conservative design parameters were adopted to evaluate lower bound safety margins.

Approaches suggested by D'Appolonia and et. al (1968 & 1970), Burland and Burbidge (1985) based on N-values and Elastic solutions of Bowels (1988) were adopted to evaluate soil settlement.

6. Other Considerations during ASM

Weather forecast : Weather forecast was obtained at every six hours starting from 2days prior to air skidding from the commercial weather forecast institute, in order to determine any weather deterioration in advance and assessed by task team.

Allowable CoG envelop for jacking-up : The center of gravity (CoG) was maintained within the allowable envelope in order to limit the load in jacking system within the permissible values, using proper ballasting.

HSE (Health, Safety & Environment) : Detail HSE study was carried out to not only guide workmanship but also accomplish 205m ultra-high-leg constructions in line with ASM procedure without any damage or injury.

7. Conclusion

The newly developed methodology, ASM, made HHI possible to fabricate Jack up legs taller than 200m on ground and overcome the height limitation due to the inaccessibility of heavy lifting equipment. Furthermore, this methodology has reduced the overall construction duration, its additional cost and ensured sufficient safety to workman participated in the project.

In conclusion, through the completion of ASM on ground this methodology has been verified. And all other necessary tests like preload & full-height test, which has been mostly carried out on the sea, have been made possible in construction yard. As well, this methodology of ASM can be applied to other fields like civil engineering.

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