Jack-up Platforms: An Overview

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Abstract:- Jack-up platforms are a type of mobile offshore drilling unit designed to provide stable support for various types of operations in the petroleum industry for the exploration and extraction of hydrocarbons from the seabed. This type of design of jack-up platforms is based on several factors, including water depth, soil conditions, environmental loads, and platform performance requirements. The platform must be designed to withstand the forces of wind, waves, and currents, as well as the weight of the drilling or production equipment. This article provides a summary of the conception, building, installation, operation, and analysis of jack-up structures. It highlights the different types of jack-up platforms, their components, and the various factors that are considered during their design, construction, and installation.

Keywords:- *Jack up platforms, Design, Operation, Construction, Installation, and Analysis.*

I. INTRODUCTION

Recent years have seen a significant expansion of the offshore structures. These structures face distinct challenges compared to onshore structures, primarily due to their location in the water. They are subjected to complex loads and impacts as a result, including pressure loads, fluid-structure interaction, powerful dynamic effects, nonlinear forces, harsh weather, and stresses. These elements have a considerable impact on offshore buildings' design, functionality, structural integrity, and performance [1 - 3] Over the last 65 years, the offshore petroleum business has seen constant technical advancement for finding, drilling, refining, and creating oil and gas [4]. The primary motivations for such continuous success are expense reduction, increased safety, reduced environmental effects, increased remote control operations, and reduced accidents. To satisfy industry expectations, new offshore permanent and floating structures have been developed. A more cost-effective approach should be taken, and more effective installation methods should be developed, to overcome the obstacles faced by the offshore firm [5]. Offshore buildings are classified into two types: permanent and floating [1]. Jack-up platforms (or jack-ups), as the name implies, are platforms that can be raised above the water using jack-like legs that can be lowered [6 - 7]. These platforms are usually used in ocean depths of up to 450 feet (130 meters), though some versions can go as deep as 560 feet (180 meters). The self-elevating jack-up rig was first constructed in 1954 and quickly became one of the most famous designs in transportable offshore drilling equipment. Jack-ups were common for drilling operations in shallow water (up to 360 feet) (110 m) [9]. Because a portion of the framework is in direct touch with the seabed, they provide a very secure drilling platform and are relatively simple to transfer from one place to another. A standard jack-up structure is depicted in Figure 1 [10].

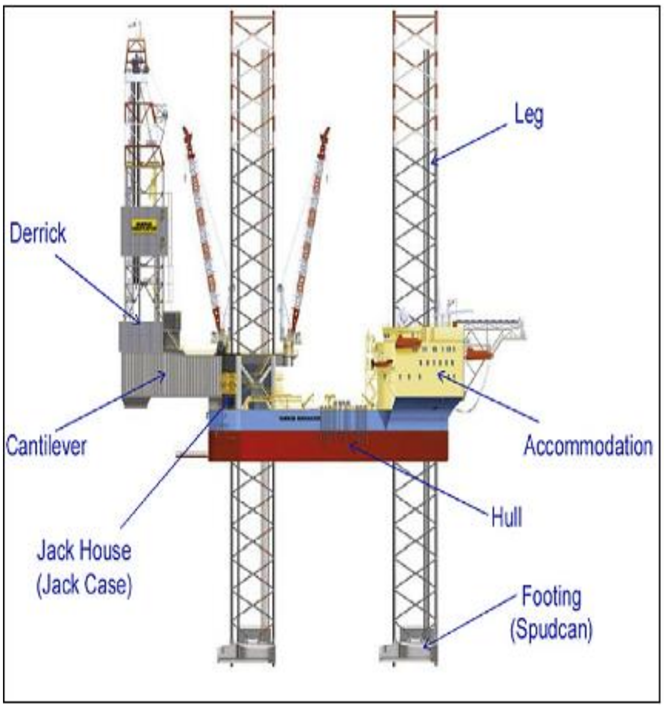

Fig 1 Established Platform Model.
Source: [8]

Offshore oil and gas prospecting, drilling, and work-over are all done using jack-up drilling platforms. In fact, during the past 50 years, the offshore industry has found them intriguing considering their versatility, capacity to raise the platform above the water's surface for a range of water depths, and capacity to serve as a stationary platform [9]. As a result, this research aims to address the jack up platform design, analysis, construction and installation.

II. JACK UP PLATFORM

- *Design*

A jack-up platform's design is a challenging process that integrates elements of structural, mechanical, electrical, and maritime engineering. The design process must take into account several variables, including soil conditions, environmental laws, sea depth, wave height, and wind speed. A jack-up platform's key parts are its hull, legs, jacking mechanism, spud cans, and power generation system. The platform's major structural component, the hull, is intended to give the platform stability and buoyancy. The platform is supported by the legs, which are typically composed of steel. The platform is raised and lowered using the jacking mechanism, which is normally driven by electric motors. The platform's weight is dispersed across a wider area with the help of the spud cans, lowering the likelihood that it may sink. The platform receives electricity from the power generation system, which is typically run by diesel generators [11]. The hull's structural elements and their roles can be summed up as follows: The design also includes cantilevered beams to support the movable drill floor, reinforced armor across the upper, intermediary, and bottom decks, upper and lower guides that create a current connection among the supports and hull, inner perimeter bulkheads that distribute hull stress to the legs, and more. The steel legs and foundations support the hull and offer stability to withstand lateral loading when the rig is operating in the raised configuration [12].

- *Leg Type*

The legs of jack-up structures can be either single cylinders or trussed constructions made of three or four chords connected by bracing (Figure 2). Contrary to cylindrical legs, trussed legs (Figure 3) require more welds, are more expensive to build, and take up more deck space. Compared to cylindrical legs, trussed legs offer several benefits. Trussed legs often weigh less than cylindrical legs for the same bearing capacity, which lowers the cost of the steel and improves stability when floating. Additionally, the area where trussed legs are exposed to the wind and water currents is reduced, which lowers the risk of loss during storms [13].

Fig 2 Cylindrical Leg
Source: [13].

Fig 3 Trussed Leg
Source: [13].

Table 1, illustrates the characteristics of commonly build jack-up rigs according to their, water depth in ft, build year, length in ft, and weight in ft.

Table 1 Characteristics of Common Built Jack-up Rigs

Rig Name	**Water Depth (ft)**	**Build Year**	**Length (ft)**
Ensco 97*	250	1980	267
Ensco 96*	250	1982	193
Ensco 94*	250	1981	193
Ensco 88*	250	1982	207
Ensco 53*	300	1982	180
Diamond M Nugget	300	1976	208
Ensco 54*	300	1982	180
Amarnath	300	1982	180
DYVI Beta	350	1978	230
Ensco 95*	250	1982	193
Generic	300	2010	193
Sagadrill 2	300	1981	194
Sagadrill 1	300	1984	194
Soraya	225	1970	177
Vicksburg	300	1976	238
Ensco 92*	250	1982	243
Ensco 87*	350	1982	243
Energy Exerter*	300	1982	245
Energy Enhancer*	300	1982	245
Generic	330	1990	255

Source: [13].

➢ *Operation*

A Jack-Up may operate in various settings due to its adaptable operating envelopes. As a result, the unit's target capabilities dictate the aspects that need to be considered throughout the design. These limits are determined by taking into account the projected top load during operations, the entire load during towing, the largest wave height, the highest operating level of water, the current velocities and winds, and the current state of the sea bottom. Jack-Up platforms, which are movable rigs by definition, can operate in one of three ways:

- *Transiting;*
- *Standing on its legs;*
- *Jacking back and forth among raised as well as floating modes.*

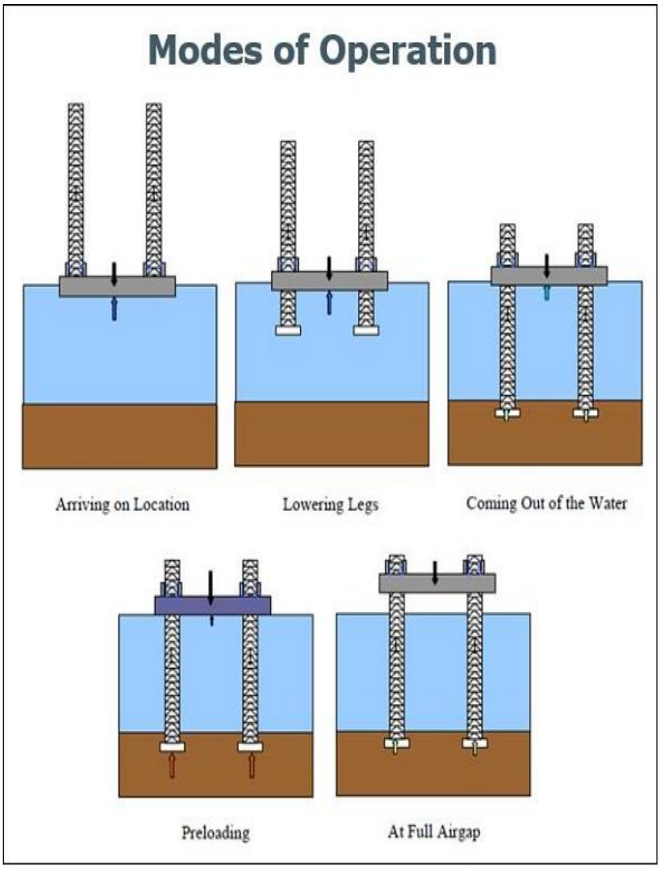

Fig 4 Modes of Operations when a Jack-Up is to Operate at a Location, Extracted from.
Source: [14]

➢ *Types of Jack-Up Platforms*

- *Platforms with Independent Leg Jack-Ups (ILJUs):*

The independent leg jack-up platform is the most popular kind of jack-up platform. It has three or four legs, and each one has a rack and pinion mechanism that enables it to be lifted and lowered separately from the others. This kind of platform is adaptable and may be utilized in a range of soil types and water depths [15-16].

- *Mat-Supported Jack-Up (MSJU) Platforms*

The legs and drilling rig are supported by a large mat- or barge-like structure on mat-supported jack-up (MSJ) platforms. Typically, this kind of platform is utilized in shallow water with a fairly level seafloor. MSJ platforms may be moved and installed with ease and are less expensive than other kinds of jack-up platforms [17-18].

- *Extended Reach Drilling (ERD) Jack-Up Platforms:*

A specialized kind of platform made specifically for drilling long-reach wells is the extended-reach drilling (ERD) jack-up platform. It can operate in deeper water and reach wells farther away from the platform thanks to its longer legs and more deck area than traditional jack-up platforms [19].

- *GustoMSC NG-5500X-LD Jack-Up Platform:*

A self-propelled hull on the GustoMSC NG-5500X-LD jack-up platform makes it possible to haul it without the aid of tugboats. It is a new type of jack-up platform. Additionally, this kind of platform has a bigger deck area and can operate in up to 85 meters of water [20].

- *Jack-up with truss legs (TLJ)*

The legs and drilling rig are supported by a triangular truss construction on truss-legged jack-up (TLJ) platforms. Typically, this kind of platform is used in deeper waters with rocky or uneven seabed. This type of platform can endure strong waves and currents, making them appropriate for usage in challenging situations [21].

- *Column-stabilized Jack-up (CSJ)*

The drilling rig and legs are supported by a large cylindrical column on column-stabilized jack-up (CSJ) platforms. Typically, this kind of platform is utilized in shallow water with a fairly level seafloor. CSJ platforms may be rapidly and readily implemented and have a minimal impact on the environment [22].

- *Mono-column MCJ (Jack-up)*

The drilling rig and legs are supported by a single cylindrical column on mono-column jack-up (MCJ) platforms. Typically, this kind of platform is utilized in shallow water with a fairly level seafloor also they are reasonably priced and have a modest environmental imprint [23].

➢ *Analysis*

The analysis of a jack-up platform requires a thorough understanding of the hydrodynamic, geotechnical, and structural aspects of the platform, as well as the environmental conditions in which it will operate.

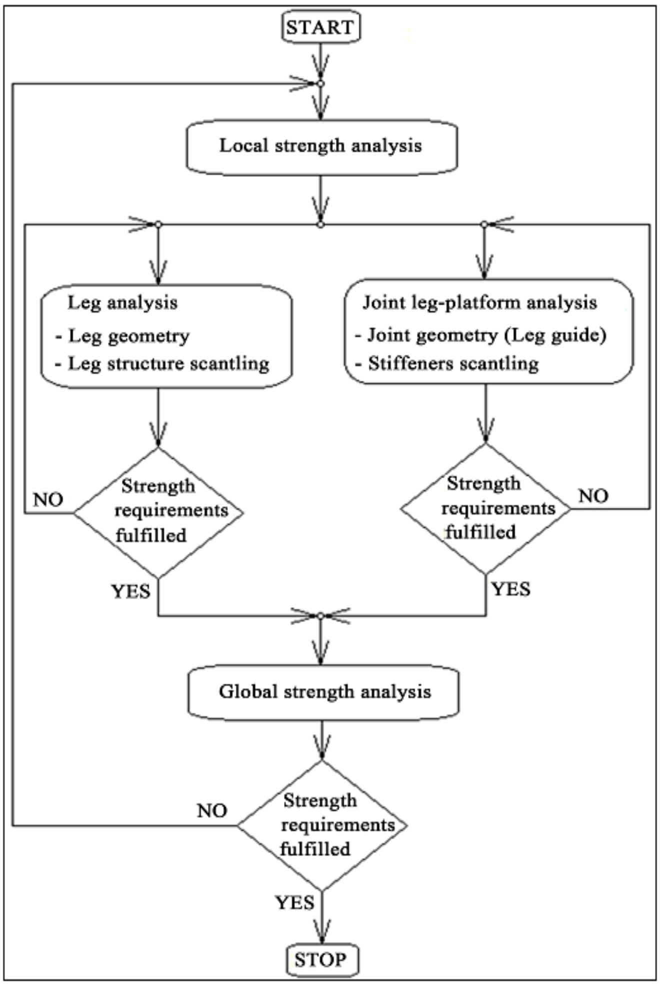

Fig 5 The jack-up analysis flow chart.
Source: [24].

Figure 5 illustrates the jack-up analysis flow chart. The following are some of the key design considerations for a jack-up platform according to [24]:

- *Hydrodynamic Analysis:*

The platform needs to be built to withstand wind, waves, and currents. In the hydrodynamic analysis, wave loads, wave frequency response, and the platform's dynamic reaction to wave loads are all determined. A nonlinear drag component plus an inertia force component make up hydrodynamic forces, according to a modified version of Morison's equation:

$$F_w = F_D + F_I \quad (1)$$

Where:

F_D: Drag Force
F_I: Inertia Force

$$F_D = \rho_w \times C_D \times D \times v \times |v|/2 \quad (2)$$

$$F_I = \rho_w \times C_M \times a \times A \quad (3)$$

Where:

ρ_w: Mass Density of water (1025 kg/m^3)
D: Effective diameter
C_D: Drag coefficient (For Reynold number greater than 1×10^3, for circular section drag coefficient is taken 1.05)
v: liquid particle velocity
a: liquid particle acceleration
C_M: inertia coefficient (For Reynold number > $1\times10^{6,}$ for circle section it should be taken 1.8)

✓ *A: Area of Member*

The formulas below are used to determine the horizontal speed and acceleration of the liquid particle for the quasi-static analysis under regular sinusoidal wave action:

$$v = 0.5 \times \omega \times h_w \times e^{-K\times z} \times \cos(K \times x - \omega \times t) \quad (4)$$

$$a = 0.5 \times \omega^2 \times h_w \times e^{-K\times z} \times \cos(K \times x - \omega \times t) \quad (5)$$

Where:

Z: Vertical coordinate from the water surface;
x: Horizontal Coordinate;
h_w: Wave Height;
T: wave period;
ω: Wave Pulsation

Where:

$$\omega = \frac{2\times\pi}{T} \quad (6)$$

For Wave Length (λ):

$$\lambda = \frac{g\times T^2}{2\times\pi} \quad (7)$$

Or Wave number (K):

$$K = \frac{2\times\pi}{\lambda} \quad (8)$$

- *Geotechnical Analysis:*

The foundation of the platform must be made to resist the site's soil and seabed characteristics. The determination of soil parameters, seabed stability, and bearing capacity are all included in the geotechnical study.

- *Structural Analysis:*

The platform's construction must be strong enough to support the weight of drilling machinery, personnel, and external factors. The platform's members' stresses, strains, and deflections are all determined as part of the structural analysis.

- *Environmental Analysis:*

The wind, waves, currents, and temperature must all be taken into account while designing the platform. The platform's reaction to these loads and the design parameters for environmental loads are both determined as part of the environmental study.

Summing the wind loading acting on all structural elements yields the overall wind force. By dividing the pressure by the i-th anticipated structural component area, the wind loading is calculated:

$$F_{w,i} = \rho_i \times A_{w,i} \tag{9}$$

Where:

$A_{w,i}$: the normal projected area of the member surface
ρ_i: Wind Pressure at the element center, given by:

$$p_i = 0.5 \times C_s \times \rho_a \times v^2{}_{z,i} \tag{10}$$

Where:

C_s:shape coefficient
ρ_a: mass density of the air
$v^2{}_{z,i}$: wind velocity in the element center

Tidal current, storm surge current, and wind-driven current are all factors in the current loading.

The Morison's formula provides the current force per unit length of legs:

$$F_c = 0.5 \times \rho \times C_D \times D \times V_C \times |V_C| \tag{11}$$

Where: V_C: Current speed, can be calculated by the following equation:

$$V_c = V_T \times (\frac{h-z}{h})^{1/7} \times V_w \times (\frac{h_0-z}{h_0}) \tag{12}$$

V_T: tidal current speed;
V_w: Wind current speed, calculated by this equation:

$$V_w = 0.0017 \times V_{RI} \tag{13}$$

V_{RI}: Wind speed at 10 m above water surface for a period of one minute;
h_0: conventional depth of water for wind current;
Z: vertical distance from water surface;
H: actual depth of water

➢ *Construction*

A jack-up platform's fabrication includes building the platform's numerous parts, including the hull, legs, jacking mechanism, and spud cans. The fabrication process can take several months and includes several steps, such as cutting steel, welding, painting, and assembling. Using computer numerical control (CNC) machines, steel plates are cut into the desired shapes during the steel-cutting process. The steel plates are coated with a protective layer during the painting process to stop corrosion. To finish the platform, the different components are connected throughout the assembly process [25]. Figure 6 illustrates the construction phase of a jack-up hull.

Fig 6 Early stage Construction
Source: [13].

➢ *The Phases of Construction The following stages are commonly involved in offshore platform construction [26]:*

- *Design and Procurement:*
  The initial phase involves conceptualizing the platform design and conducting engineering studies to determine the specific requirements and feasibility. This phase includes structural design, stability analysis, load calculations, and determining the necessary equipment and systems.

- *Construction:*
  In this phase, the various components of the jack-up platform are fabricated. These components include the hull or legs, spud cans, jacking systems, living quarters, machinery, and other equipment. The fabrication can take place in different yards or facilities, and the components are built to the specifications provided by the design team.

- *Load-Out:*
  After the integration of systems, load testing is conducted to verify the platform's strength and stability.

- *Transportation and Installation:*
  Once the jack-up platform passes all the necessary tests and inspections, it is ready for delivery to its intended location.

- *Commissioning:*
  This phase includes testing the propulsion system, emergency systems, and safety equipment, and conducting trials to evaluate the performance of the platform in various operational scenarios.

➢ *Installation*

The installation of the drilling equipment, comprising the derrick, drill floor, and other equipment, is the last step in the setup of a jack-up platform. There are multiple steps in this operation, including preparing the equipment for installation, transporting it to the platform, and installing it on-site. There are typically two methods for raising a rig's deck. First, pneumatic pistons with movable and fixed pins are used. The cylinders expand and contract while moving up and down the Jack-Up rig's legs. The second mechanism raises and lowers the legs continually using racks and two pinion gears. The raising system's jacks are usually sufficient to lift and drop the hull. The hull's main body is however susceptible to bending moments brought on by horizontal wind, wave, and current forces both in operation and in inclement weather. during some units use raising pinions to transmit these loads in all modes of operation, while others only do so during jacking and spend the majority of the time in all other modes with a fixed system [12]. The installation of jack-up structures involves transporting the platform to its final location and installing it on the seabed. A pre-installation survey, mobilization, jacking-up, spud-can penetration, and final placement are some of the processes that make up the installation procedure. To determine if the seafloor can sustain the platform, a pre-installation survey must be conducted [27]. Utilizing a transportation vessel, the platform is moved during the mobilization stage to the installation location. The platform is raised using the jacking mechanism during the jacking-up phase until it is above the water line. To provide the platform with more support, the spud cans are lowered into the seabed during the spud-can penetration stage. In the last phase of positioning, the platform is precisely positioned using the jacking system [28].

III. CONCLUSIONS

In summary, jack-up platform design, analysis, building, and installation are intricate and intertwined processes. For these structures to be safe and functional in offshore conditions, advancements in these fields are essential. They are ideal for drilling activities in shallow to medium-depth seas because of their stability and ability to self-elevate. These platforms' adaptability and mobility enable exploration and extraction in numerous offshore fields. Jack-up platforms have many advantages, but they must be carefully designed, built, and operated to take into account things like water depth, environmental conditions, and safety laws.

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