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PROBLEMS AND SOLUTIONS IN THE OPERATION OF JACK-UP AND DRILLING

Introduction. Jack-up barges (self-elevating drilling platforms) and simpler anchored drilling barges are widely used in offshore oil and gas operations for exploration and near-shore field development. A jack-up barge is a mobile platform with a buoyant hull and extendable support legs that can be lowered to the seabed to lift the deck above the water (usually above the wave zone). These units typically have three (or occasionally four) triangular lattice legs and a large hull weighing millions of pounds. In operation, the legs are jacked down through the water into the seabed until the hull is held above waves. Jack-ups are commonly used for offshore drilling in water depths up to roughly 150 meters, offering mobility and cost-effectiveness in shelf environments. By contrast, drilling barges (swamp barges) are flat-bottomed barges with a cantilever derrick that are towed to a site and held in place by an 8-point mooring system. These barges have low freeboard and limited seaworthiness, restricting their use to very calm waters in shallow depths (typically <50 m).

These platforms operate under harsh offshore conditions (waves, currents, winds, and cyclic temperature changes) and must withstand corrosive saltwater exposure. As the demand for deeper drilling and heavier equipment grows, the loads on hulls and legs increase, challenging the design limits. At the same time, aging structures, sometimes with deferred maintenance, plus strict safety and environmental regulations, create engineering and operational issues. This work examines the main technical problems in jack-up and drilling barge operation and discusses modern solutions to improve reliability, stability, and service life.

1. Structural Features and Operating Conditions. Jack-up barges consist of several key components:

- **Hull/Pontoon:** a watertight barge-shaped hull that supports the drilling deck, living quarters, and machinery. It provides buoyancy and carries the cantilever drilling package and jacking house.
- **Legs (support columns):** usually three lattice legs (occasionally four) extending below the hull. The legs are fitted with spud-cans or footings at

the bottom that rest on the seabed. A lifting mechanism (commonly rack-and-pinion drives with pinions engaging racks on the legs) raises or lowers the legs, so that during deployment the hull is supported by the legs on the ocean floor.

- Deckhouse and Superstructure: above-deck facilities include the drilling rig, power plant, and living quarters.
- Jacking System: mechanical or hydraulic jacks in the hull (jack house) engage the legs. Typical systems use multiple rack-and-pinion hoists (one per leg) to lift the entire platform evenly.
- Ballast System: tanks and pumps in the hull for trimming and stability control during tow and preloading.

During transportation, the legs are fully raised and the hull floats on water. At the drilling site, the legs are lowered until they contact the seabed. The legs penetrate as needed (preloading) to achieve a firm footing, and then the jacking system elevates the hull up to the required air gap above the water surface. The spud-cans provide bearing and prevent excessive settlement. In shallow waters, a drilling barge will be moored by anchors instead. Both types of platform must contend with wave and wind loads on the hull and legs, current forces on the structure, and the constant exposure to a corrosive marine environment. In particular, salt spray and chlorides in the splash zone (the cyclically wet region near the waterline) create very aggressive corrosion conditions.

2. Main Operational Problems

2.1. Corrosion and Fatigue Degradation

Corrosion is a primary factor limiting the service life of offshore platforms. Saltwater, humidity and oxygen promote metal oxidation, leading to coating breakdown and material loss. Jack-up hulls, legs and deck equipment are exposed to a combination of salty air and immersion; this results in uniform corrosion of topside structures and severe pitting in splash and submerged zones. Indeed, marine corrosion in the oil&gas industry costs billions of dollars annually, and jack-up platforms (with exposed steel legs and large wetted areas) are especially vulnerable. Corrosion damage reduces the thickness and strength of structural members, undermining load capacity. Over time, localized corrosion at welds or edges becomes crack initiation sites, accelerating fatigue failure of welded joints. In practice, this means more frequent dry-docking for repair, increased risk of ballast-water leaks from corroded bulkheads, and eventual failure of pins, jacking lugs or fasteners in the hoisting gear.

Environmental factors combine to worsen fatigue and corrosion: cycles of temperature and stress fluctuate material properties, and mechanical loading interacts with the chemical attack. Laboratory and field studies have shown that saline air and humidity amplify oxidation rates, while repeated loading under corrosive conditions causes “corrosion fatigue,” dramatically shortening component life. For example, repeated drilling vibrations and wave impacts, together with corrosion, will generate fatigue cracks more rapidly than in benign conditions. In summary, corrosion leads to reduced leg capacity, cracking of welds, and spalling of coatings – necessitating extensive maintenance and posing safety risks.

Key consequences of corrosion and fatigue include:

- frequent maintenance outages (dry-docking) to repair thinning hull plating and replace corroded segments.
- local leaks or flooding due to perforation of ballast tanks and structures in the splash zone.
- failures of jacking-system components (e.g. stripped gears, pin failures) caused by undetected fatigue cracking.

2.2. Dynamic Loads and Stability

Jack-up operations are strongly affected by dynamic seabed interaction and environmental loading. Unpredictable geotechnical conditions (soft clay layers, sand seams, uneven seabed) can cause differential leg penetration. If one leg suddenly sinks (“punch-through”) more than the others, the platform will tilt. A leg “punch-through” (rapid unplanned penetration) is a known hazard in jack-up installation; it can happen during leg lowering or even at working height if a weak soil layer fails. Such asymmetry induces complex load shifts and bending moments in the hull and legs. Even small tilts are tightly limited (e.g. tilt limits are typically on the order of 0.25–0.5°) to prevent equipment damage. Unintended tilting risks safety and can halt operations.

In addition, the platform in raised position is subjected to oscillatory forces from waves and wind. Periodic wave impacts on the hull and legs induce vibrations and cyclic stresses. These dynamic loads contribute to high-cycle fatigue in leg-to-hull joints, spud-cans and deck structure. Drilling operations themselves cause vibration (especially torsional and axial vibrations in the drillstring) which can transmit to the structure. Over time, this combination of offshore wave/wind loading and machinery vibration accelerates fatigue damage in welds and steel members. Managing these cyclic loads requires robust design and careful leveling but remains challenging when unexpected soil movements occur.

2.3. Jacking System Failures and Positioning Errors

The jack-up's lifting system is a complex, heavily loaded mechanism. Any failure in a jack or drive train (e.g. hydraulic actuator fault, motor stall, chain or gear failure) can cause one leg to lag or drop, immediately creating uneven load distribution. In practice, an unsynchronized lowering of even one leg causes the platform to incline, often triggering an emergency halt. For stability, leg loads must remain balanced and the hull kept level (typically within a few tenths of a degree). Faults such as worn rack teeth, seized guide rollers or hydraulic leaks can disrupt this balance. Similarly, for anchored drilling barges, loss of an anchor line (due to line failure, fouling or inadequate tension) leads to unplanned rotation or drift and uneven mooring loads, compromising stability. Positioning errors at sea (e.g. due to tug handling or anchor dragging) make accurate placement difficult and may require re-positioning, adding risk. Overall, failures in leg jacking or anchoring pose serious stability and safety hazards.

2.4. Limited Maintenance Access and Monitoring

Offshore platforms have crowded decks and confined spaces for machinery, making inspection and maintenance difficult. Critical components (leg guides, jacking racks, ballast compartments) may be hard to access. Traditional inspection methods (visual checks, ultrasonics) often require the rig to be shut down or at least secured, which is costly in lost operating time. Space constraints and the presence of drilling hazards (heavy equipment, petroleum gases) further limit maintenance operations. As a result, problems often go undetected until they become severe. The lack of integrated real-time condition monitoring means many defects are only found during scheduled dry-docks or after minor failures. This “reactive” maintenance approach can lead to unexpected downtime and expensive emergency repairs.

2.5. Environmental and Fire/Blowout Risks

Despite modern safety systems, drilling platforms inherently involve high risk of blowouts, oil spills and fires. The presence of flammable hydrocarbons in the drilling fluid and annulus means that well-control failures (e.g. loss of well pressure, faulty blowout preventer) can rapidly escalate into uncontrolled eruptions of oil or gas. Historical incidents on drilling barges, such as the 1964 C.P. Baker barge disaster, illustrate the danger: a blowout flooded the hull and ignited a massive fire, resulting in the barge sinking and many fatalities. Similarly, aged or damaged fuel and hydraulic piping or worn seals on any offshore structure can leak oils into the sea, causing environmental contamination. Fuel spills from ballast or

bunkering operations also pose pollution hazards. Additionally, offshore fires (from engine rooms or drilling systems) can quickly spread in the compact quarters of a platform. In summary, blowouts and hydrocarbon leaks remain among the most severe risks for jack-up and drilling barge operations.

3. Modern Engineering Solutions

In response to these challenges, the industry is applying various engineering and procedural improvements to enhance safety and longevity. Current strategies focus on protecting structures, improving system reliability, and utilizing advanced monitoring. Key approaches include:

3.1. Enhanced Corrosion Resistance

To combat marine corrosion, multi-layer protective systems are standard. These often combine cathodic protection (either sacrificial anodes or impressed-current systems) with robust coatings. For example, jack-up hulls and legs are fitted with sacrificial zinc or aluminum anodes; in some cases impressed-current cathodic protection is applied to maintain the submerged parts at a protective potential. High-build epoxy primers and polyurethane topcoats (in multiple layers) are used on hull and deck surfaces to isolate steel from the environment. These coatings significantly slow corrosion rates, especially in the splash zone and submerged areas. For high-risk components (leg guides, pinions), corrosion-resistant alloys (e.g. duplex stainless steels) or inorganic zinc-rich primers may be used. Routine re-application of coatings during periodic maintenance is now standard. Research into advanced coatings (e.g. self-healing epoxies and nano-composite films) is promising: such materials can autonomously seal small scratches or release inhibitors when damaged.

3.2. Improved Jacking Systems and Leveling

Modern jack-up designs incorporate redundancies and better controls in the leg jacking system. Hydraulic pinions with precise servo control, automated leveling algorithms, and backup chains reduce the chance of catastrophic failure. Some newer rigs use dual-drive motors per leg or cross-connected hydraulic circuits so that one leg's actuator can assist another. Real-time load-sensors on each leg allow the control system to detect uneven loading immediately and adjust movement rates. Automation software now routinely enforces equalization of leg movement (to within millimeters) during lifts. In addition, design improvements such as stiffer guides, enhanced lubrication, and enclosed seals protect the rack-and-pinion gears from contamination and wear. For anchored barges, newer mooring systems use synthetic fiber ropes with real-time tension

monitoring and automatic capstans that can re-tension any slack, minimizing rope failure.

3.3. Monitoring, Diagnostics and Digitalization

A major innovation is the deployment of integrated monitoring systems and “smart” diagnostics. Sensors (strain gauges, accelerometers, ultrasonic probes, corrosion probes) can be installed on critical components (leg towers, jacking gears, hull plating) to collect real-time data on stresses and degradation. For example, load sensors on each leg track axial and bending forces during jacking and drilling, alerting operators to anomalies. Environmental sensors measure hull acceleration in waves, which combined with a hydrodynamic model, predict excessive fatigue cycles. On-line corrosion probes and corrosion-rate transmitters can detect coating failures early. All this data can feed into digital monitoring systems (SCADA) for continuous oversight.

Moreover, operators are beginning to use digital twins and predictive analytics. A digital twin is a computer model of the rig that simulates its structural response under current conditions. By inputting sensor data (e.g. leg load, wave height, soil stiffness), the model can predict the platform’s response to imminent operations or extreme events. Similarly, machine-learning algorithms analyze historical sensor data to predict the time-to-failure of components (e.g. jacking motors or welds). Studies have shown that predictive analytics can identify areas prone to severe corrosion or fatigue well before visible damage. Implementing these techniques enables condition-based maintenance: parts are serviced or replaced just before failure would occur, rather than on a fixed schedule. This reduces unplanned downtime and improves safety.

3.4. Standardized Inspections and Maintenance Practices

To address the human and procedural side, the industry is also standardizing inspection routines and crew training. Well-defined checklists and periodic dry-dock surveys (often using robotic crawlers and magnetic crawlers for hull inspection) help ensure no critical areas are missed. Companies now often require marine warranty surveys and independent audits of jack-up operations, verifying that all procedural controls (e.g. proper preloading, tilt limits, drilling protocols) are followed. New off-shore maintenance concepts like “stay time” planning and parallel maintenance tasks help minimize total downtime. While these are organizational measures, they effectively reduce the risk of oversight errors in maintenance and operation.

Conclusions and Outlook. The operation of jack-up and drilling barges in the offshore environment involves multiple interrelated technical challenges: corrosion, dynamic loading, mechanical reliability, and safety risks. Our review shows that corrosion protection, system redundancy, real-time monitoring, and maintenance optimization are key pillars of current solutions. In particular, integrating predictive diagnostics (using sensors and analytics) and digital twin simulations into routine operations offers great potential to extend platform lifespan and avoid failures. Future work should continue developing smart coatings and condition-monitoring technologies, and formalize their use in industry standards. In conclusion, a comprehensive approach combining improved design, technology, and procedures is needed to enhance the reliability, safety and sustainability of offshore jack-up platforms.

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