SPUDCAN DESIGN AND SURVEYS – PAST, PRESENT AND FUTURE

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ABSTRACT
The design of jackup spudcan structure has evolved over decades of application, and it is important for owners and designers to have an inspection regime that uses practical experience and data to guide future surveys and match the design criteria in terms of critical structural areas and possible failure modes. Owners, classification societies, vendors, shipyards, and designers are getting access to additional data gathering and analysis tools as well as improved remote inspection techniques, and these have the potential to further develop industry knowledge. In the future, sensors and connected technologies may be used to provide more timely health information in addition to calendar-based surveys and maintenance activities. This paper describes how the ABS classification rules for self-elevating drilling units have developed into the current requirements, based on experience and observation representing thousands of jackup rig-years in service worldwide. Normalized, anonymized data are shown to illustrate lessons for various rig types and ages. We also present paths forward for practical joint efforts to further improve the understanding of spudcan structures and how to evaluate their condition.

KEY WORDS: offshore, jackup, spudcan, structure, survey, inspection

INTRODUCTION
The jackup rig market originated in the 1950s as the first self-elevating platforms were developed to move drilling operations offshore. The American Bureau of Shipping (ABS) published the first classification rules (Mobile Offshore Drilling Unit, or MODU, Rules) for these units in 1968[1] and has been further developing and modifying the rules continuously since then. The International Maritime Organization (IMO) published its first Code for Construction and Equipment of Mobile Offshore Drilling Units (MODU Code) in 1979 [2] and has updated the Code in the intervening years. The MODU Code sets general goals for structural aspects which are aligned with the detailed requirements of classification rules, and the most recent Code in 2009 [3] specifically references compliance with class requirements.

Classification societies involved in the offshore industry have made considerable advances in researching and implementing rational criteria for offshore units, including design and survey verification. In particular the evolution of the requirements for jackup legs and spudcans has progressed to reflect the nature of the loads involved in transit and operations and the need to adequately verify the health of the structures while acknowledging the practicalities of offshore operating schedules.

There have been, and continue to be, hundreds of jackups in service around the world in drilling service. Non-drilling jackups also serve as maintenance or accommodation units and there is an increasing number of units devoted to the growing offshore wind industry for installation, inspection, maintenance and repair tasks.

The operational history and survey findings from this fleet can provide valuable information to correlate with the evolution of design and survey criteria as we seek ways to further improve the methods to assess health of the structures involved.

SPUDCAN DESIGN
For many years the design of the spudcan was based on various first principles methods for loads and strength. There were no specific classification rule criteria for the structure of a spud can and designers used their own experience to address meeting the anticipated structural loads.

Following several decades of jackup operation and considering the ongoing work in standards forums such as the site assessment groups in the Society of Naval Architects and Marine Engineers [4] and International Organization for Standardization (ISO) [5] it became clear that the knowledge of jackup loading, response, and structural adequacy had improved and it was necessary to embed that information in the design criteria in the class rules rather than in guidelines or commentary from various sources.

So in 2008 the ABS rules [6] were modified to reflect several important aspects of leg and spudcan design. For the elevated condition the dynamic response of the unit was included, and consideration of the so-called "P-Δ" (P-delta) effect from non-axial loads was also introduced. Offsetting these factors was the inclusion of bottom fixity and spudcan-soil interaction rather than assuming only a pin-ended condition. For the spudcans, a new section was introduced into the rules to explicitly define afloat mode scantlings based on deep tank requirements, and elevated mode is to be based on the maximum preload condition for design of the can plating and connections to the legs.

These changes were introduced to align the rules with current knowledge and practice, particularly with the site assessment process which is outside the classification regime but uses similar methodologies.

The 2008 update has had a noticeable positive effect on survey findings for spudcans, which will be discussed later.

SPUDCAN SURVEYS

Class survey requirements also developed and evolved between the earliest jackup rigs and the year 2008.

Beginning in 1968, the MODU Rules comprised annual surveys, annual drydocking surveys (but could be extended to two years), and a four-year cycle of special periodical surveys (SPS) albeit with a year of grace available under special consideration. The SPS included "all underwater structure is to be examined."

Subsequent rules published in 1973 [7] changed the drydocking to "intervals not to exceed 2 years." The annual surveys included "special attention should be paid to the structure in way of joints or connections of supporting legs", and guidance that the hull portion can be partially credited for structures seen while elevated. For the SPS it was noted that the "entire structure is to be carefully examined externally and internally" and "particular attention is to be given to all supporting legs and intersecting support members and non-destructive testing may be required for the joints between the legs and supporting members at critical connections."

In 1980 [8] detail was added for annual, intermediate and SPS surveys. Significantly the concept of unit age was introduced as the SPS has comprehensive requirements based on how many special survey cycles have been completed. Leg-to-spudcan connections were also to be subject to nondestructive examination.

In the mid-80s the "window" concept was placed in the rules to set defined start and completion dates for surveys. Then in 1997 the SPS changed to a 5-year cycle removing the 4+year of grace. Drydocking surveys were not to exceed 2.5 years apart. Spudcans were to be examined internally as well as externally after SPS number 2. Further change in the drydocking schedule came in 2001, going to twice in a five-year period but no more than 3 years apart to give more operational flexibility to owners.

By 2008 specific SPS requirements were added for close visual inspection and non-destructive examination on jackup legs including:

i) Leg-to-spudcan connections plus 2 bays of leg above the top of the spudcan
ii) Jackhouse/jackcase-to-deck connections
iii) Brace-to-chord connection in areas of leg that have been predominately in way of the upper and lower guides.

At the same time, the underwater in lieu of drydocking (UWILD) criteria which had been in an appendix (and prior to that, a separate Guide) were brought into the rules.

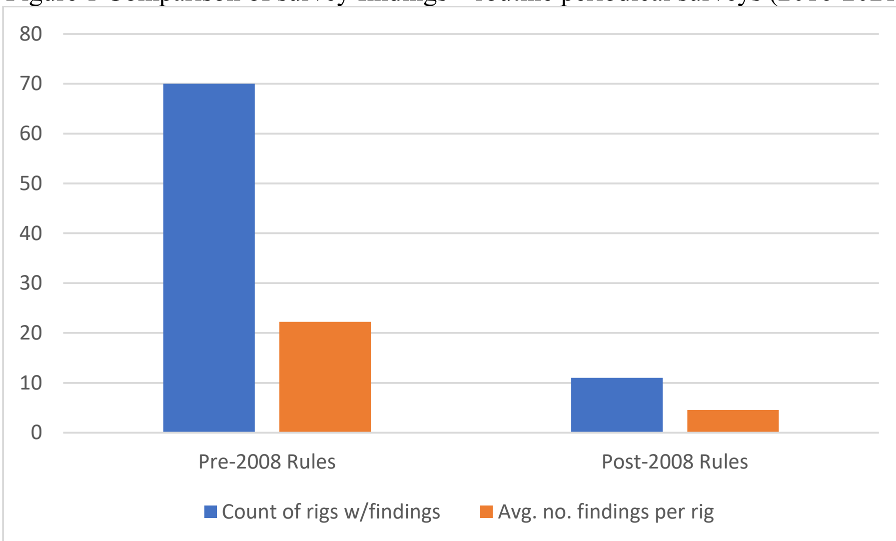
So, by 2008 there was a comprehensive design and survey regime in place reflecting analysis of loads and responses and the associated verification of condition in service.

EFFECT OF DESIGN CRITERIA

From an analysis of spudcan findings for ABS classed jackups covering the period 2016 through mid-2021, a difference can be seen in frequency of survey findings associated with spudcan damage whether they be fracture, indent/deformation, bucking etc. A "finding" in this context is a recorded observation or recommendation from a survey attendance. The findings were documented through routine surveys in the 5-

year cycle for the units (annual, drydocking/intermediate, and special periodical) and exclude damage surveys where an owner requested attendance after issues were encountered offshore. There is a clear reduction in both the raw numbers and the count of rigs involved for jackups where the spudcans were designed to the 2008 rules requirements. See Figure 1.

Figure 1 Comparison of survey findings – routine periodical surveys (2016-2021)



The number of findings is also affected by age of the pre-2008 units which date back to the 1980s and earlier. In general, the older rigs had a higher number of findings per vessel. The types of findings show some interesting trends such as increased bucking and distortion in older spudcan structures (in addition to wastage/corrosion) as compared to newer units.

Many of the older units operate in more benign areas, however, so it is difficult to compare with some of the newer high-specification designs with higher loads and different soil conditions.

Further work in evaluating the effectiveness of design criteria will need input including location, bottom conditions, and utilization of preload capacity. These factors will also feed into the survey regime as it becomes more data driven for unit type and even per individual unit.

FURTHER SURVEY DEVELOPMENT

The changes in design criteria were followed by analysis of survey data and discussion of methods and frequency for examination of the spud can and leg connections with a view to reviewing the process and focusing effort where it is most needed.

The year 2012 saw the new requirement to identify "structural critical areas" based on design and service history, and inclusion in a Survey Planning Document (SPD) to be retained on the unit. The SPD forms the basis for future decisions on survey planning by incorporating knowledge about highly stressed or fatigue prone elements identified by calculation, or areas of concern from past surveys. The rules also allowed deferral to the next rig move of drydocking survey or UWILD survey for the spudcans if the unit was elevated. Requirements were added covering the scope of internal spudcan examinations and gaugings at special periodical surveys. In 2014 further SPS details were added depending on rig age, and internal examination of spudcans was removed from the scope of intermediate drydocking surveys unless there were external indications of damage.

Beginning in 2017 alternative criteria were introduced and subsequently refined, for reducing the required scope of examination at intermediate UWILD surveys on spud cans on newer units. The alternative can be applied when all of the following are true:

a) There is no history of eccentric spud can loading or scour since last spud can examination associated with a Special Survey

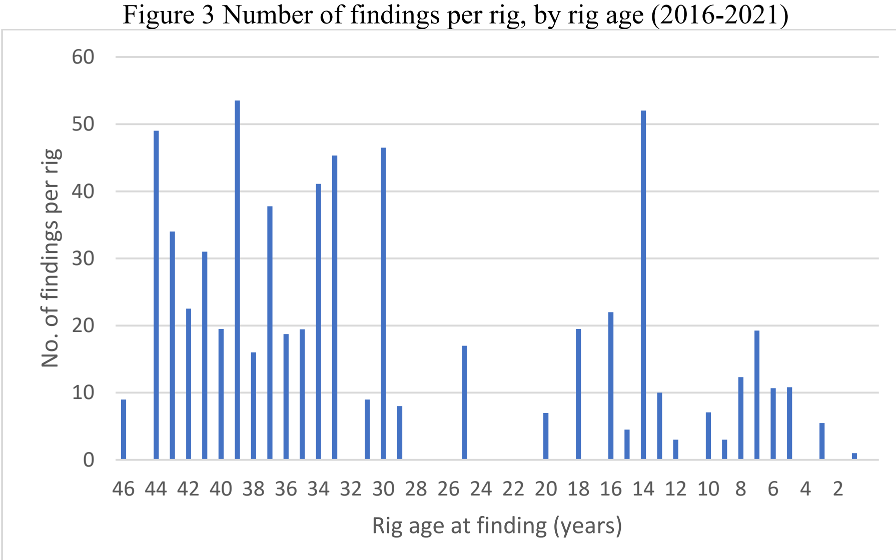
b) Rig design meets the 2008 and newer MODU Rules for spud can design criteria
c) Operational history of unit is clear of structural indications
d) No substantial corrosion has been observed in the spud can and leg connections

For units meeting all of these criteria, intermediate UWILD surveys use general visual examinations and limited non-destructive testing (except where problems are identified visually). Designated areas of the spudcans are checked and these are included in the Survey Planning Document; one or two cans may be examined instead of all three depending on age. These modifications to the rules have been well received by the jackup owner community. The general external examinations can be carried out remotely by employing remotely operated vehicles (ROVs) or divers in conjunction with a surveyor observing video in real time.

DATA ANALYSIS

There is a clear trend of increased findings for the older rig fleet. See Figure 3, showing findings normalized to the number of units. Note that individual damage surveys or reactivations can cause "spikes" in the data as compared to periodical surveys where there have been no reported rig incidents causing serious leg/spudcan damage. There is also the normal sparsity of data in the ages corresponding to the low construction era in the late 1980s and through the 1990s.

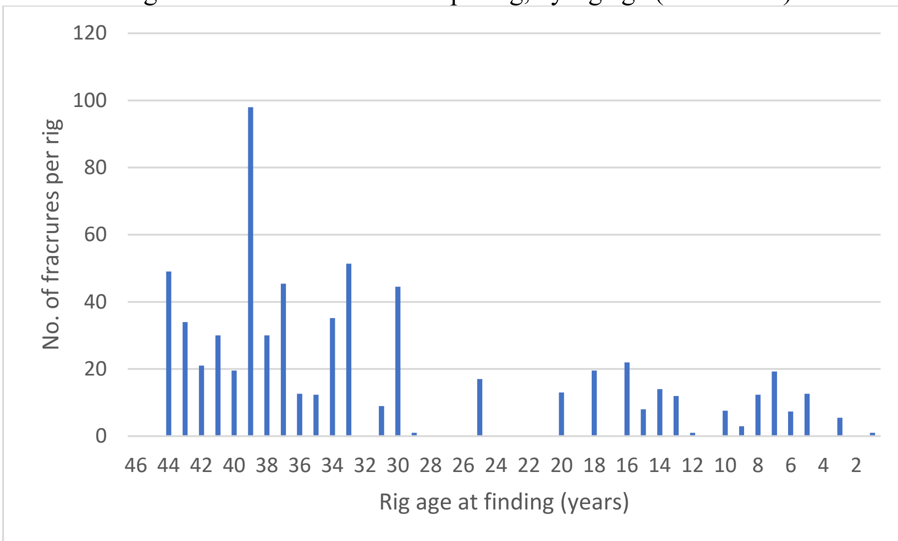
Figure 3 Number of findings per rig, by rig age (2016-2021)



Using the basic information we have now on survey findings, it is possible to parse the data in many ways to evaluate processes and imply areas for change. We have already seen that there is a clear effect from the 2008 spudcan design rules, that age of the rig is still an important factor, and that there are variables that could be added to better define true root causes.

Using this approach it is possible to group the data by survey type (e.g. routine periodical vs. damage/repair), or finding type (fracture, wastage, indentation, etc.). For example, see Figure 4 showing findings tagged as "fracture" only: no deformation, wastage, tripping and so on.

Figure 4 Number of fractures per rig, by rig age (2016-2021)



It is also possible to analyze findings by owner, by rig design type, by general operating area, by These are not presented here for commercial privacy reasons. The methodology allows surveys to be planned with the owner based on the history of their fleet and the particular unit in question.

A few qualitative observations have come from the data as well. For example, some damage can be avoided by conducting the minimum preload necessary; it is the preload operation that is reported to cause many structural findings in the legs. The vulnerability of the spudcan conical "tips" is also fairly apparent as there is an observed pattern of damage or detachment in hard bottom areas. The design and installation of jetting lines is also an associated concern as damage to this piping and its supports can have effects on the leg and can attachments.

NEXT STEPS

As electronic systems improve we have more access to data that can be used to inform the survey requirements. Analysis of findings data continues, to identify areas of concern or topics for improvement.

In addition to the existing data captured for specific surveys, it has been noted above that location information would be helpful as an input so that metocean history and bottom conditions can be made part of the data analysis so findings can be grouped and compared. Defining survey needs for a region, service type, or rig design may be possible in the long term if such data can be reliably collected and correlated. This will be important for non-drilling units such as maintenance jackups and wind turbine installation units with higher frequency of jacking operations associated with such tasks.

A logical future step would be more frequent data capture from jackups using sensors and data uplinks. A "Smart" application based on the ABS Guide for Smart Functions for Marine Vessels and Offshore Units [8] could be envisaged for certain critical areas to be part of Structural Health Monitoring (SHM). Increased health monitoring of critical structures may allow for more timely survey and repair, as there are records in the 2016-2021 data which indicate that a damage event may have occurred to the spudcan structure but this had not been apparent to the owner. Such approaches can help move toward a more diagnostic, predictive, and health-centric view of the unit which drives tailored decision making about survey priorities for each specific jackup.

CONCLUSION

Collecting and using data can provide a path forward for improving the physical understanding of the jackup spudcan structural capability. Data quality is key, and systematic approaches need to be applied to account for the nature and consistency of the data so that valid and useful conclusions are drawn.

Cooperative work with the jackup community of owners, designers, and builders can be of great assistance to continuously improving survey requirements, which can have benefits for operational availability by moving away from a fixed calendar-based checklist approach. In the long term we can use our collected knowledge, experience, and data to develop geographic, design-specific or even rig-specific criteria. The basis for this would be “live” Survey Planning Documents and onboard Smart diagnostics and prognostics which reflect the analysis, survey history, and service history of the rig.

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