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The assessment of the operational suitability of mud pumps on deep water drillships depends on maintenance strategy

Tomasz Piasecki✉**, Artur Bejger, Maciej Kozak**

Maritime University of Szczecin, Faculty of Marine Engineering
1–2 Wały Chrobrego St., 70-500 Szczecin, Poland
e-mails: piaseckitomasz83@gmail.com; {a.bejger; m.kozak}@am.szczecin.pl
✉ corresponding author

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Abstract

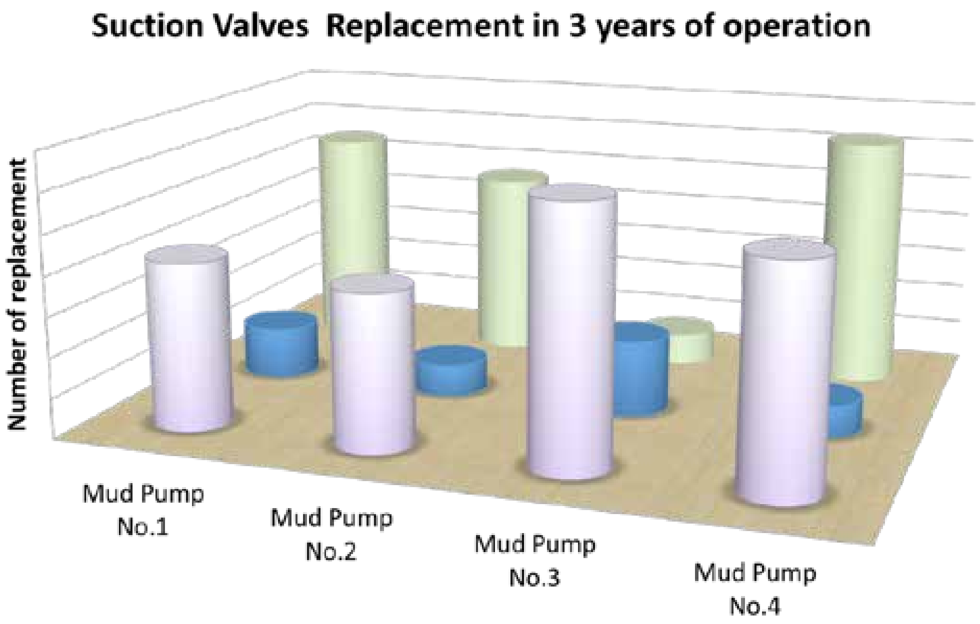
This article examines the differences in the lifetime of mud pumps, which are part of the equipment on (ultra) deep-water drillships, depending on the strategy of maintenance. The authors conducted research on mud pumps to create an efficient diagnostic tool to help pumps operators on daily maintenance routines. We have created drilling process diagrams, one pertaining to the operation of mud pumps for which maintenance is carried out without technical supervision, the other including diagnostic maintenance. The diagrams show differences pump failure frequency.

Introduction

Each drilling process is associated with the operation of a number of devices that are subject to frequent damage (Collier, 1983; Romagnoli & Bosio, 2003). In fact, even the shortest downtime caused by technical fault may lead to a huge economic loss. Some of the running devices are subject to control of selected operating parameters. Although system monitoring is a major aspect of technical supervision, it is sometimes impossible to identify and locate the point of failure. In the course of operations, a variety of external factors affect machines and equipment, both objective (meteorological, biological and mechanical excitations) and subjective (to what extent operational principles are observed, qualifications of users, etc.). These factors tend to have a random character, which also means that the characteristics of the tested objects are also random in nature (Niziński & Michalski, 2002; Bejger, 2012). It follows that **objects that have worked for the same period may be in completely different technical conditions**.

In the case of mud pumps installed on drillships, operational supervision of machines is carried out either continuously or periodically. Regardless of the adopted maintenance system, there are no tools to predict the occurrence of a failure. The authors of this paper are working on the development of a method and design of a diagnostic system aimed at detecting, at an early stage, changes/disturbances in the operation of a machine. Such a system should not affect the drilling process, and permit to plan a repair as soon as practicable (without an emergency shutdown of the running machine).

To confirm the importance of the issue, we have analyzed, over the past three years, a number of failures associated with mud pumps in one of the deepwater drilling rigs. It has been shown that the most common type of failure is referred to suction-discharge valves of said pumps (Figure 1). Our studies have also shown that the periods between repairs differ significantly from those recommended by the manufacturer (Figure 2). These differences are due to the treatment of muds having varied chemical



	Mud Pump No.1	Mud Pump No.2	Mud Pump No.3	Mud Pump No.4
Emergency due to leak	42	39	64	55
During survey	13	8	19	8
All replacements	55	47	8	63

Figure 1. Analysis of the failure rate of suction-discharge valves of mud pumps on drillships

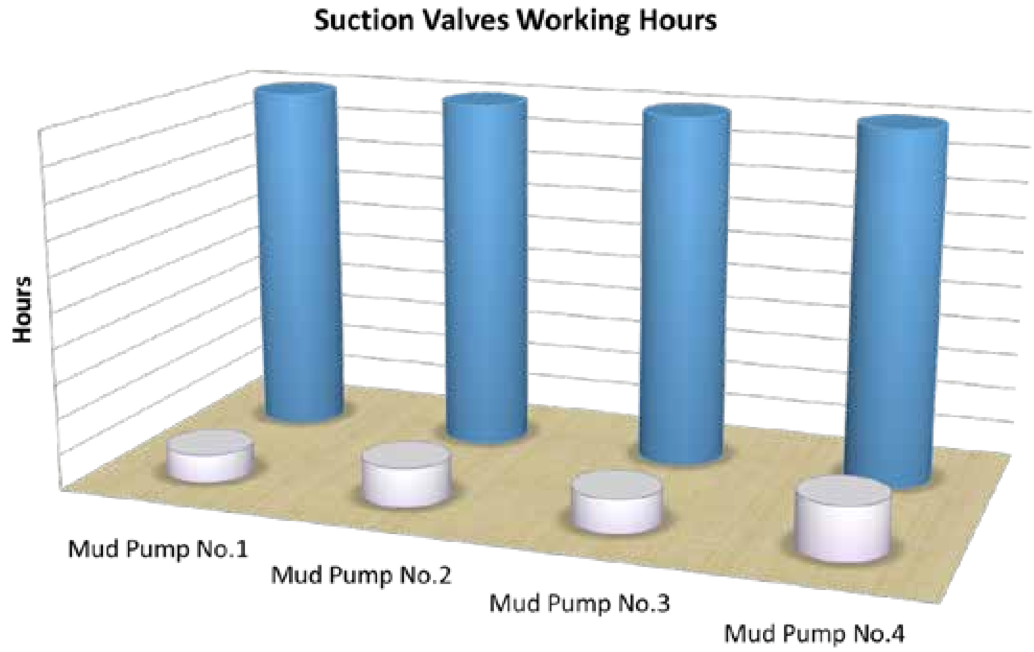
composition, the quality of operation, and the adopted maintenance strategy.

Analysis of maintenance strategies for mud pumps of drillships

In machine operations, four main strategies of maintenance can be distinguished (Żółtowski, 1996; Żółtowski & Ćwik, 1996):

1. **Maintenance until failure**: in this approach failures occur unexpectedly. The advantage of such maintenance strategy is the low investment on diagnostic equipment and maintenance personnel training. The basic disadvantage is that the secondary effects that may occur can cause significant financial losses and reduce the safety of users (their lives may be at risk).
2. **Time-dependent maintenance, or time between overhaul periods (TBO)**: where the operation is conducted according to the established plan. Preventive maintenance and repairs are carried out at fixed intervals. The advantage of TBO is the fixed period between repairs, when the operation of machines can be planned. The great disadvantage is that often the actual resource, or operational capability of a machine/component is not fully exploited. The exchange is preventive, without any real knowledge of the condition of the replaced item.
3. **Diagnostics-based maintenance (depending on current technical condition)**: repairs and inspections are carried out depending on the current state of the machine detected by diagnostic methods.
4. **Prediction-based maintenance**: on the basis of certain symptoms or using diagnostic signal descriptors, we can detect early changes associated with a failure, even before there is a clear change in operating parameters. Thus, a repair can be planned, for instance during idle time of the machine (between periods of work).

For mud pumps used on offshore ships, one of the first three strategies is usually adopted, although diagnostics-based maintenance (diagnosis of the current technical condition of an item) is used only to a limited extent. The occurrence of a fault (noticeable critical pressure drop and fluctuations in the system) may be ascertained, but the location of the leaking module may be difficult to identify. For instance, too many disturbances present in the pump room will exclude the use of the vibration method (Bejger & Piasecki, 2013; 2014). If a leak is detected, the whole drilling process has to be stopped, generating losses in the order of 20,000 dollars per each hour of downtime.



	Mud Pump No.1	Mud Pump No.2	Mud Pump No.3	Mud Pump No.4
Real	800	1100	950	1500
Estimated	10000	10000	10000	10000

Figure 2. Comparison of actual and manufacturer-recommended time until a failure of mud valves on a selected drillship

The running hours of mud pumps have been analyzed for two extreme strategies of maintenance – without technical supervision (maintenance to the point of failure) and with technical supervision (according to TBO).

The drilling process diagrams have been developed for both strategies – one where mud pump failures occurred (representing the maintenance without technical supervision – Figure 3) and one in which technical supervision was adopted (Figure 4).

The diagram representing the drilling process for the operation of mud pumps without technical supervision (Figure 3) shows the course of actions/operations, including the period of pump failure. When holes are drilled in the Managed Pressure Drilling (MPD) system, it is important to maintain a predetermined bottom hole pressure in the wellbore. Each pump failure causes pressure drops and fluctuations. The loss of drilling mud pressure stability (which provides a suitable pressure on the borehole

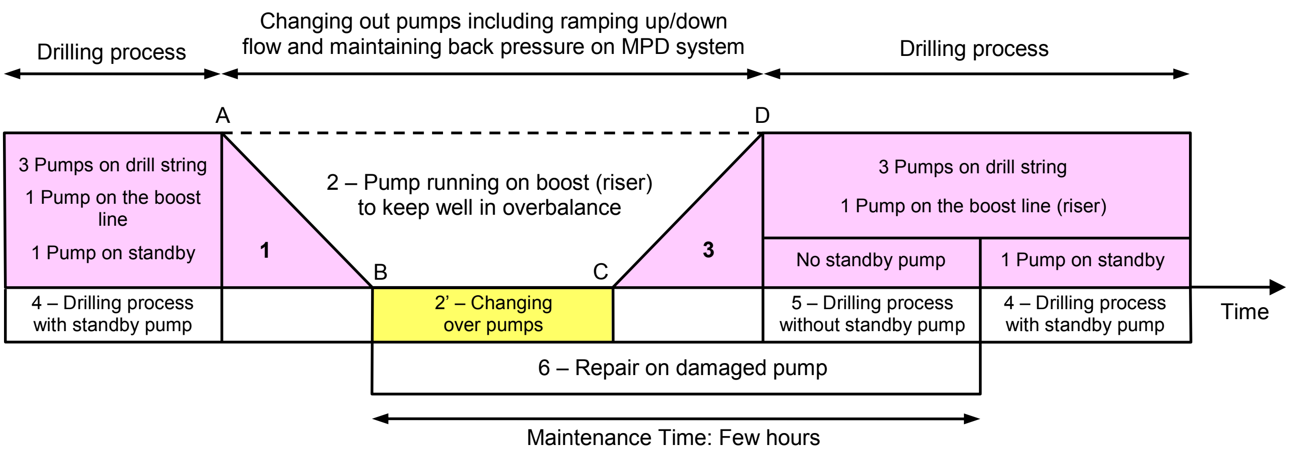


Figure 3. Diagram of the periods of operation of the MPD process and the strategy of mud pumps maintenance without technical supervision (until failure)

wall) results, among other effects, in reduction of the friction between the drill string and the borehole wall, disturbance in the cooling of the drill head, or improper flushes of the cuttings (elevating them to the surface).

An analysis of mud pump maintenance allows us to distinguish the following specific points related to the adopted strategy of maintenance:

4 – The process of drilling in which three pumps are set for delivering mud into the drill string, then through the pipe to the drill bit and, finally, along the borehole back to the mud pits (ADITC Limited, 1997; Mitchell, 2006). One of the pumps is set for pumping mud along the riser above the blowout preventer. One pump is standing by, so if one of the mud pumps fails, its operation can be replaced by the standby pump, thus drilling may continue uniterrupted. The pump changeover, however, is not possible without stopping the drilling process (unlike typical pumping systems onboard ships, where a broken pump is automatically switched off and a standby pump takes over the operation in the system).

1 – The period during which, following the detection of a pump failure, all pumps pressurizng the drill string are stopped. It is essential that one of the pumps that discharges mud to the riser immediately above the blowout preventer is used for maintaining positive pressure in the wellbore. The pumps are stopped really carefully, so that by means of special choke valves to maintain a constant (precise) back pressure for the overpressure provided at the bottom of the borehole.

2 – The period wherein the pump delivering fluid to the riser pressurizes the borehole. The process of drilling is stopped for the time of pump changeover.

2' – The period of withdrawal of the damaged pump, and insulating the valves after the damaged pump.

3 – The period in which the pumps discharing mud to the drill string are started up, the pressure on the pumps is restored also very carefully, with full control of the choke valves in order to maintain an appropriate back pressure to achieve the required positive pressure in the drill string.

5 – The period in which the drilling process is continued without a standby pump which took over the work of 'shut down' damaged main pump. Any other damage to one of the other pumps also entails downtime in the process of drilling.

6 – The repair period (subject to strict, specified repair procedure). The first step is to prepare the necessary technical documentation and obtaining permits for the repair (including electro-mechanical insulation), which absolutely must be reported to and approved by the person in charge. Next, when the electro-mechanical insulation is removed, the pump can be dismantled and repaired. The average repair time, for the most common damage of the valve unit, lasts a couple of hours. The first step alone, preparation of spares and repair permits takes about one hour.

A − The moment of detecting the failure (leakage). This is a critical moment because the available diagnostic method ('listening' method is presently in use) allows detecting an existing leakage, caused by substantial wear of an item, which means the drilling process has to be discontinued, the pump switched off and repair begun.

B − The moment of stopping the pumps, shutdown of the damaged pump, and switching over to the standby pump.

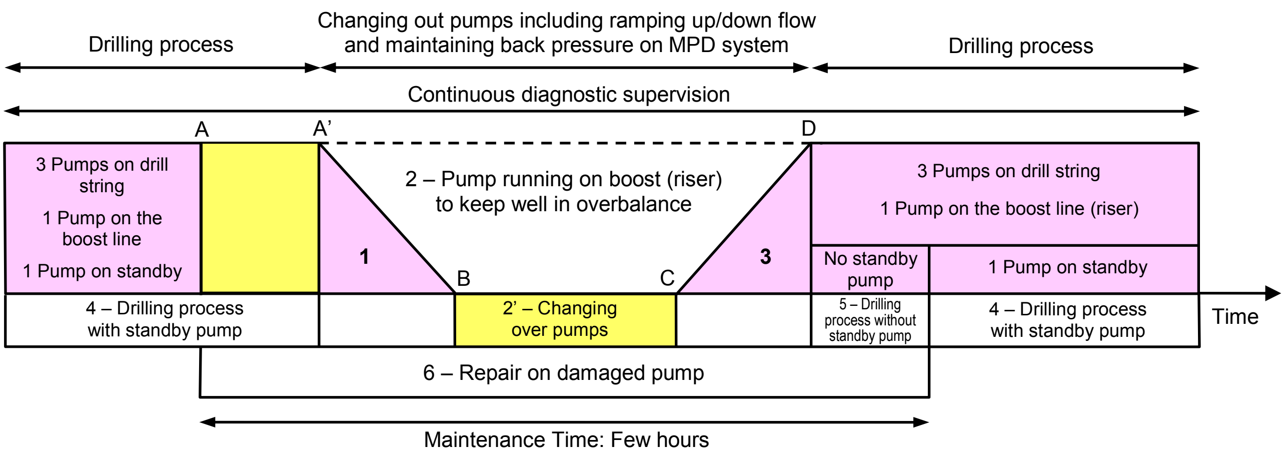


Figure 4. Diagram of the periods of operation of the MPD process and the strategy of mud pumps maintenance with technical supervision

C − The moment starting the other pumps necessary for the drilling process to be normally continued.

D – The moment at which all the pumps are started again and the drilling process is resumed.

Technical supervision practcally implemented allows detecting an evolving fault in a valve module at an early stage. What follows such detection is that the pump can still be operated for a specified time with continuous diagnostic supervision. At the same time the maintenance personnel can prepare the damaged pump for repair (obtain permits, prepare the necessary repair kits) when it is still running. Point A (Figure 4) represents the moment of failure detection, but the defective pump can continue work.

Point A', however, corresponds to the time in which the maintenance team is ready to replace the damaged part, so the damaged pump can be shut down and standby pump started. The time interval AA' cannot be predicted, it can range from several minutes to a few hours, depending on external factors such as: the material the valve was made of, or the type of drilling fluid (mud). These two factors in actual operation are not known. As a rule, they are selected by independent companies.

Conclusions

The article explores the available maintenance strategies employed in the drilling process on deep water drillships. A failure analysis covering devices of the drilling system installed on ships showed that components of the valve module, part of a mud pump, are subject to most frequent failures. We can generally conclude that maintenance strategies used so far are not effective and the lack of application of diagnostic systems capable of detecting early states of pump faults is critical, resulting in lengthy and costly downtime. We are working on the system itself and analysis of diagnostic signals obtained in order to be able to <u>predict</u> the condition of mud pumps. Current field studies show at the initial stage confirmed the usefulness of elastic waves of acoustic emission (AE) for diagnosing valve modules in mud pumps. The high frequency diagnostic EA signal causes the overlapping low frequency signals from the background and adjacent machines to get suppressed. With a properly selected measuring point, the signal reaching the sensor comes from one particular nearby source − in this case from the diagnostically relevant valve module.

Currently, a publication is being prepared on specific diagnostic tests of the devices referred to in this article.

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