Journal of Geotechnology and Energy | vol. 38 | no. 3 | 2021 | pp. 13–18

https://doi.org/10.7494/jge.2021.38.3.13

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A NEW NON-INTRUSIVE CONDITION MONITORING SYSTEM DESIGNED TO IMPROVE RELIABILITY OF RCDs

Date of submission:
4.10.2021

Date of acceptance:
19.10.2021

Date of publication:
31.10.2021

Abstract: Managed Pressure Drilling (MPD) is a technology that allows for precise wellbore pressure control, especially in formations with uncertain geomechanics. The Rotating Control Device (RCD) is a crucial part of the MPD equipment but is prone to failure. Therefore, a new condition monitoring system was developed to improve the reliability of RCDs and eliminate their catastrophic failures during MPD jobs. Non-intrusive sensors were selected during the design of this condition monitoring system. Sensors measure: vibrations, acoustic emissions, rotation, pipe movement, temperatures, and contamination level in the coolant fluid. The system can display the measurements in real-time to the operator, giving early warnings to prevent the RCD's catastrophic failures during the job. Additionally, the data is recorded to allow further processing and analysis using ML and AI techniques.

Keywords: Managed Pressure Drilling, condition monitoring, Rotating Control Device, MPD, RCD

1. Managed pressure drilling background

The primary role of the drilling mud in traditional oil and gas well drilling operations is to lubricate the bit, clean the well from the cuttings, and provide hydrostatic pressure. Traditionally, the mudflow system is open to atmospheric pressure, and drilling mud is typically the first line of the well control practice and a pressure overbalance is established with a specially selected drilling mud density to allow for safe drilling operations. However, it is estimated that around 70% of the hydrocarbon resources available offshore cannot be drilled economically using conventional drilling techniques [1].

An alternative method to control bottom hole pressure can be achieved with the Managed Pressure Drilling (MPD) technique. MPD is currently more and more widely utilized to address pressure profile uncertainty, wellbore ballooning, and loss circulation problems within the industry. The MPD equipment package includes a Rotating Control Device (RCD) and a choke manifold to establish a closed-loop system and regulate the pressure from the surface. The goals for successful MPD operations are to detect the downhole pressure environment's limitations and alter the annular hydraulic pressure profile accordingly [2]. By eliminating well control concerns and immediately altering bottom hole pressure when necessary, MPD increases safety and decreases Non-Productive Time (NPT).

The RCD is one of the most important components because it maintains a closed system by providing a pressure seal on the hydrostatic column while permitting pipe movement. The typical RCD comprises two components, as shown in Figure 1: a stationary housing called the RCD bowl that sits on top of the BOP stack and rotating seal elements with a bearing mechanism inserted inside the RCD bowl collectively known as the bearing assembly. A hydraulically actuated clamp and a safety bolt are frequently used to lock the bearing assembly in the RCD bowl. This bearing assembly provides the pressure seal and rotation, making it a closed-loop system.

The MPD significantly reduces this risk by containing the returns and diverting them away from the drilling floor, where a potential hazard of gas at the surface is continuously present during conventional drilling operations, putting the safety of the rig crew and all personnel around the rig at risk.

Additionally, the MPD systems can quickly detect the hydrocarbon influxes, giving sufficient time for the drilling crew to regain control over the well in a very short period.

Figure 2 shows the flow path through the closed RCD system, which enables drilling in a closed seal environment while rotating. The RCDs are currently manufactured and tested to the API 16 RCD, where various pressure cycling and pipe manipulation tests are required to qualify the new equipment [3]. However, during the typical MPD job, the environment and forces acting on the RCDs can differ from the environment where the RCDs were tested. As a result, there are occasions where premature RCD failures can occur. Catastrophic failures of the RCDs usually can occur without a significant warning to the operator. They can result in risky drilling scenarios such as well control issues, well stability issues, and stuck pipes.

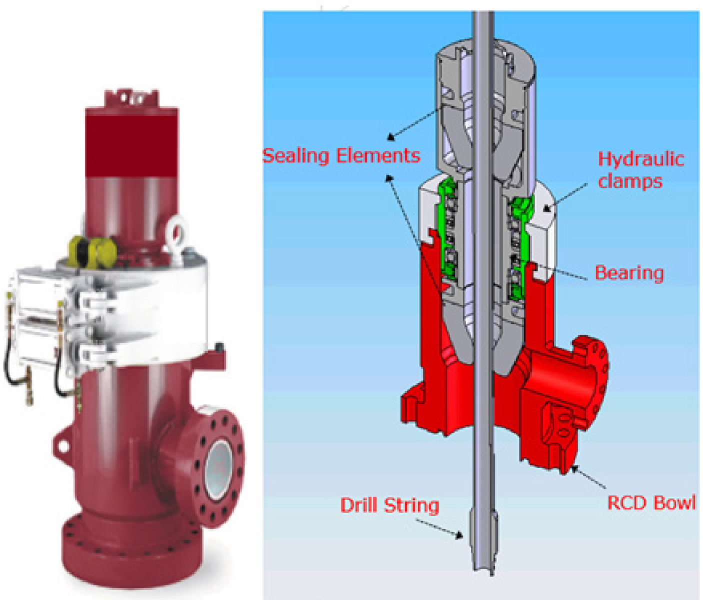

Fig. 1. Rotating Control Device assembly

Source: Weatherford

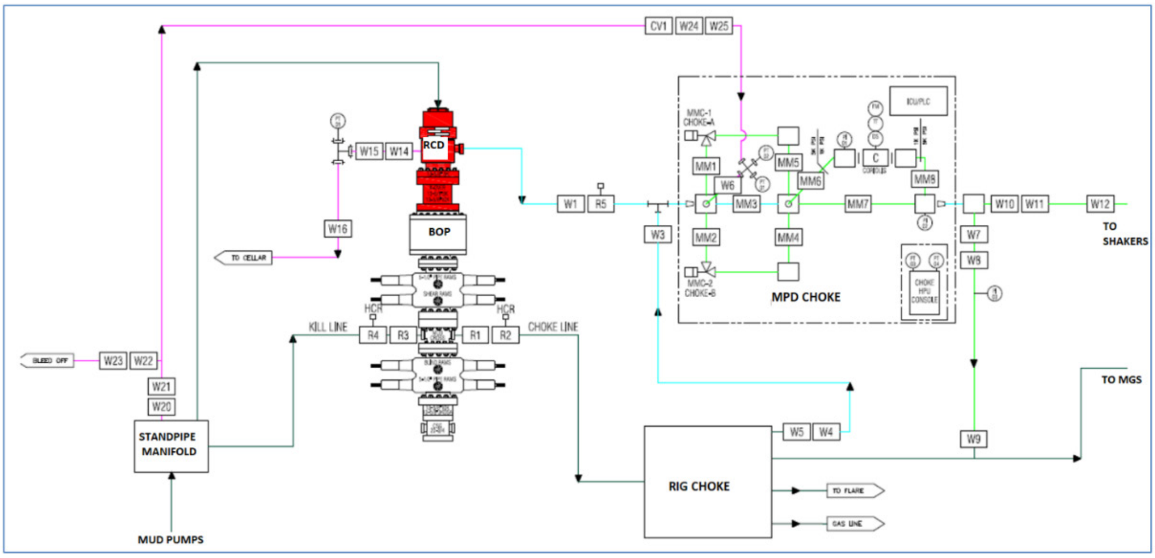

Fig. 2. RCD and MPD flow-path

Source: Weatherford

2. Common failures with RCDs

The RCD is critical equipment that enables the entire MPD technique. Even though the current operators implement strict maintenance procedures tied to the recommended hours of rotation and footage stripped threshold to avoid premature failures, there are still occasions of seal leakages and catastrophic equipment failures. The following are the most common failures:

1. RCD sealing elements leak as a result of defective seals.
2. Seizures in RCD bearings, leading to seal deterioration and leakage.

Capturing and understanding the causes that cause RCD failures is essential to increase the reliability and improve the safety of the MPD operations. Furthermore, understanding and eliminating the causes of the RCD failures can extend the RCD life and provide more conclusive recommendations for early bearing assembly replacement.

3. RCD monitoring system requirement

The continuously changing environment from one job to another for the RCDs and random failures of this equipment has encouraged developing a condition monitoring system to understand better the factors leading to premature RCD failures.

The operational requirements for such a condition monitoring system covered the necessity to operate during drilling activities covering Zone 0, Zone 1, Safe Zones, high ambient temperature, and dust particles usually preset while drilling in the desert. The new system was required to be non-intrusive to avoid any modifications to the existing MPD system and operational procedures. The newly developed system consists of a portable, add-on jacket with various sensors mounted on the RCD. This system was designed to operate in a Passive Mode, collecting data and plotting the results in real-time to the operator in the field on an integrated Human Machine Interface. At the early stage of the development, this system wasn't intended to give any suggestions to the operator to avoid potential false alarms before a sufficient data analysis was performed first.

4. Sensors and measurements

Various non-intrusive sensors are installed directly on the RCD and related MPD drilling machinery.

Figure 3 shows the position of the sensors as well as the overall clamp-on system. The sensors listed below were selected and positioned to allow for the measurement of the following:

Rotational Speed Sensor – monitoring the relative speed of rotation of the Top Drive, the drill pipe, and the RCD bearing assembly. The primary function of this sensor is to monitor for any rotational slip between these components. For example, a difference in rotational speed could suggest a problem with bearings or seals.

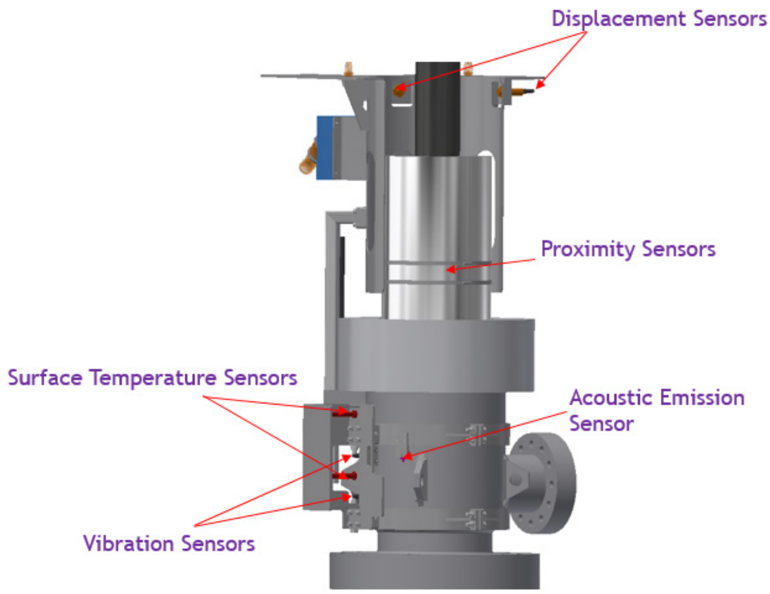

Fig. 3. 3D model of a RCD condition monitoring system mounted on a dedicated RCD

Source: Aramco Overseas Company

Displacement Sensors – monitoring the position of the drill pipe relative to a stationary datum. This is determined using an array of proximity sensors, as is the drift of drill pipes relative to the Top Drive and the RCD. Two displacement sensors are used to check for any potential misalignment between the Top Drive and the RCD. The displacement sensors also track the movement of drill pipes into and out of the well.

Vibration Sensors – the RCD's vibration sensors monitor the vibrational signature from the interactions between the seal and the drill pipes and the integrity of the RCD's bearings. Vibration data also offers information on the system's response to the ongoing drilling operations.

Temperature Sensors – measuring the RCD housing temperatures to determine any change of the conditions that can cause temperature change inside the housing, which are not dependent on the environmental temperature changes. It is expected that some temperature changes might come from the change of the friction factor in the bearings and the seals or temperature changes of the drilling fluids.

Acoustic Emissions Sensor – mounted on the housing, attempts to detect acoustic-related events related to the RCD responses due to drilling events and the seal and bearing element condition.

Each sensor is connected to Data Acquisition System. The system design allows storing raw data from the sensing equipment with a corresponding time and date stamp. The data is saved on various mediums, including integrated local storage, removable SD as a backup, and removable USB for further data analysis. Simplified data processing was applied at this early phase. Data from the sensors is processed locally within the central unit. Results are displayed to the operator in real-time in two primary forms: pre-set level alarms and visual graphs that monitor trend deviations. Collected data is displayed on an integrated display on the central unit Human Machine Interface (HMI), allowing the operator to interact with the system, read and adjust the alarm levels, modify graphs for more precise analysis, set some basic parameters, download data to USB.

The processed data is used to trigger simple alarms and to provide feedback to the operator. These alarms are communicated to the operator in the form of visual and sound events. At the early stage, they help with self-troubleshooting the system by detecting any readings significantly off the scale to check the system and sensors if they are functioning correctly. All the collected RAW data can be transferred directly from the central unit to a dedicated device for more sophisticated analysis.

5. On-field installation and operation

The condition monitoring system was created with the user in mind, making it simple to set up and appropriate for usage in a Zone 1 hazardous area during drilling activities. All the sensors were pre-attached to an add-on jacket to allow easy installation to the RCD bowl, along with a certified junction box for hazardous conditions to gather signals from each of the sensors. The junction box was connected to the HMI and powered with the aid of a multicore cable. The HMI was placed inside the MPD container providing shelter against the high temperatures and significant dust usually present in desert environments.

This new equipment was complemented with monthly tests checks and the maintenance schedule, ensuring the equipment's durability even in the most extreme conditions.

6. Data from first jobs and results

The RCD condition monitoring system has been successfully deployed and tested during the MPD job in the field. The initial field testing was mainly focused on assessing the successful development of the entire system and confirming the whole package is functioning correctly. All the sensors have successfully communicated with the data gathering unit. As a result, the main measurements were in the expected ranges, and graphical charts with data were obtained on the HMI display on the data acquisition system available to the MPD operator during the job.

Essential sensor readings were acquired, downloaded, and shared to seek potential system upgrades, apparent trend deviations, and plan for more sophisticated data analysis. Figure 4 shows a visual representation of the gathered data gathered from the system during an MPD job.

During the first field deployments, various drilling events were observed, recorded, and displayed to the operator in real-time. During the specific drilling activities, specific trends were starting to form.

The system has recorded unique signatures related to running pipes in the hole, drilling, and pulling pipes out of the hole. The proximity sensors detected the tool joints passing through the RCDs, allowing calculating the tripping pipe speeds. Corresponding vibration signatures were also recorded with changes related to the different drilling activities. These readings were successfully displayed to the operator in real-time during the job.

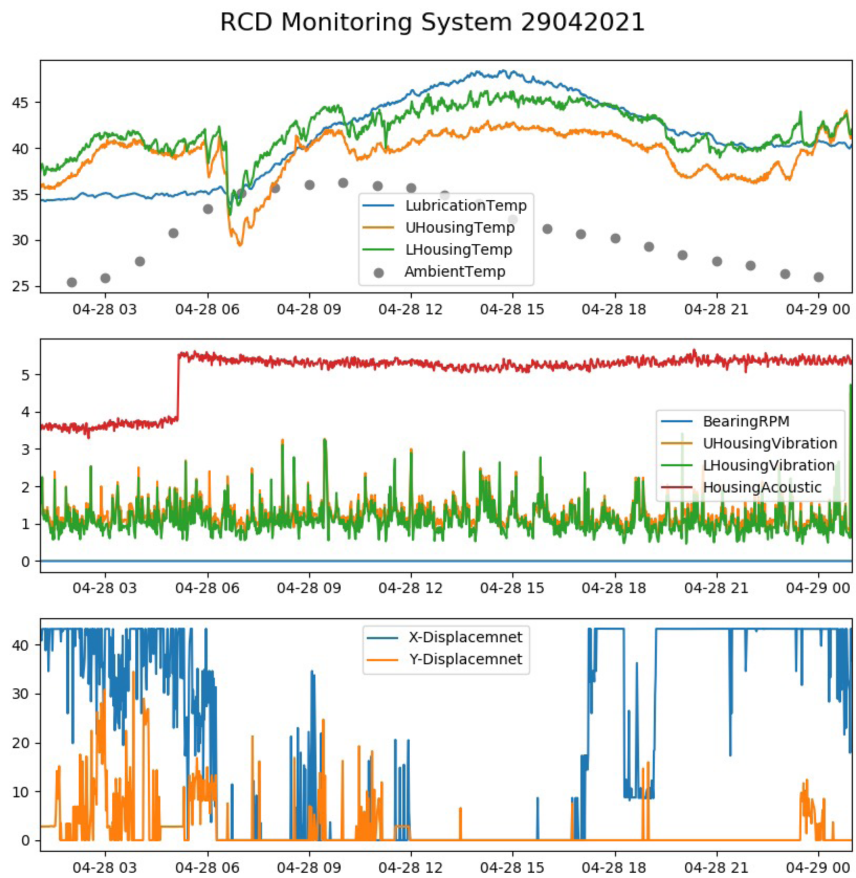

Fig. 4. Collected data displayed on a three charts

Source: Aramco Overseas Company

7. Summary and conclusions

The RCD monitoring system is an add-on jacket designed to be installed on the RCDs, in the field, during the MPD jobs to monitor their health. All sensors included within this system are non-intrusive sensors. They allow monitoring temperatures, vibration, acoustic emissions, pipe-RCD misalignment, and RCD-pipe relative rotations. The readings are presented to the operator in an easy-to-understand format to alert the operator about any substantial trend deviations and prevent catastrophic failure. The data acquired will be used in later stages to predict the time-to-failure of the RCD in bearing and seal elements, allowing for safe corrective steps. Currently, the system is operating in a passive mode, collecting data. More data is being collected in additional field jobs to improve data analysis, identify applicable trend deviation limits, and predict a safe operating window for critical MPD operations. In addition, more data is expected to aid in quantifying the health of the RCD sealing and bearing components.

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