Problems Analysis on Preparation of Oil and Gas Drilling Rig Installation for Next Operations Readiness after HPHT (High Pressure High Temperature) Well Operation

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Abstract. Oil and gas drilling is an activity designed to bring oil and gas resources into the surface of the earth using drilling rig. One of the characteristics of drilling wells is HPHT (High-Pressure High Temperature) condition, where this type of well can reach temperature of 150 °C and pressure of 15,000 psi. Due to these extreme conditions, the drilling rig installation often need to be serviced after it operates under HPHT condition before it can be operated again. The influences of HPHT wells conditions to the equipment component in the drilling operation systems are studied to find out the probable failures root cause that make the drilling rig break down and have significant Non-Productive Time (NPT) after operated on HPHT well. During this study, we found out that the root cause of the problem is failed to apply a detailed program and company revenue. The problems become more significant for the rig performance and its NPT thus affecting the overall drilling program and company revenue.

1. Introduction

The recent phenomena of drilling exploration activity is at a well that has a pressure level and temperature that exceeds the common condition wells in general. This recent condition is commonly called as the High Pressure High Temperature (HPHT) well. These HPHT category wells are Oil or Gas wells that have reservoir temperatures above 150 °C and reservoir pressure above 10,000 psi [1]. Problems caused by the condition of HPHT wells to the components of the oil and gas drilling rig equipment become a serious problem. The oil and gas drilling rig which is just finished been operated on HPHT wells have a down time before it is ready for the next operations. Many damages have been found on the equipment components when the rig is being maintained and serviced. These conditions resulted in a significant delay of the rig readiness since the equipment cannot be used directly, so that the whole drilling operation plan must be temporarily stopped. There are several systems in the oil and gas drilling rig installation that working together. However, if one system fails, then the whole installation cannot operate and the drilling operation must be stopped. Every system in the installation have its own influence and crucial to each other. Oil and gas drilling operation is an expensive operation and based on operation time, so the costs are directly related to delays and extensive working time [2]. The purpose of this study is to analyze the situations in order to determine the effect
of drilling wells with HPHT conditions on the performances of the drilling rig equipments, and to find the root cause for some of major equipment components of the drilling process that are broken.

2. Methodology
The study was carried out using 2 methods. First, by desk evaluation, which all the works of the systems were studied from the rig installation manual, technical service bulletin and drilling operation textbooks. Previous cases, broken equipment components, system failures and other anomalies that occurred in relation with drilling operation on HPHT wells before were gathered from operation problem reports, rig installation after operation reports, rig installation preparation reports as well as rig log books. All relevant informations were examined and analyzed. Since most of all data are previous data or secondary data, therefore, the desk evaluation study was limited to qualitative analysis and results. The second method were field and real operation observation, as well as failures probable cause investigation on the operating rig installation in the field and servicing rig in the workshop. Results and conclusions of the study were compiled in order to determine the probable root cause of equipments failures due to operation on HPHT well and for historical data as well as planning the drilling operation improvement in the future.

3. Results and discussion

3.1. Background analysis
Time for drilling rig installation preparation after HPHT well operation for its next operation task is Non-Productive Time (NPT) since the rig during this time is being serviced and is unable to make any income for the company. NPT consists of time durations that are used for servicing several equipments of the rig installation. Chronological data of the rig installation NPT can be used to get an overview of the failures that occurred, when the failure occurred, the actions taken for the failure and the total down time caused by the failure.

![Figure 1. Non productive time of the components [3]](image)

Figure 1 above shows the NPT data of a particular object drilling company after operation on HPHT well. It is revealed that the largest percentage of NPT is the mud pumps equipment of 68.99% (225.5 hours) and the second large percentage is the solid control equipment of 14.26% (46 hours) from the total non-productive time (NPT) of 325.5 hours [3].

3.2. Damages findings
From problem and repair reports of the rig equipment when in service after HPHT well operation, there are six significant problems/damages/failures on drilling equipment components as shown in Table 1 [3]. Mostly, it consist of the damages occurred on Mud Pump equipment that operates directly
on the drilling mud which also directly in contact with the HPHT conditions in the well. Drilling mud fluid are circulating into the HPHT well from outside through pumping process by the mud pumps [4]. Therefore, the mud pumps and the circulating system are the equipment components that are directly interact with the HPHT conditions through the drilling mud fluid.

### Table 1. Equipment components damage signs [3]

| No. | Findings                                      |
|-----|-----------------------------------------------|
| 1   | Knocking and Smoke on the MP2                 |
| 2   | Failure on the MP2 Crosshead Bearing          |
| 3   | Washout on the MP2 Wiper Seal                 |
| 4   | Scratch on MP2 Liner                          |
| 5   | Failure on the MP2 Rubber Piston              |
| 6   | Clogged up Lubrication Line 3/8” on the MP2   |

#### 3.3. Problem analysis

Based on the finding data in Table 1, the first signal of failure of the mud pump 2 was smoke and knocking sound from the crosshead bearing damage that generate heat, smoke and broken component. After the pump was disassembled, it was found that the crosshead bearing was damaged.

![Figure 2. Heavy damage of crosshead bearing](image-url)

Based on other data, i.e maintenance records, it was found that the wiper rubber seal was washout. The washout wiper seal condition causes the wiper seal to malfunction in holding the liner water from entering the pump chamber. Therefore, the oil used for the lubrication was contaminated by water and it causes the lubrication to underperform. Lubrication is an important factor for bearings. Another unreported and unnoted data, based on field direct observation and operator’s confession, the screen for filtering the coarse materials from the mud fluid was not the real screen as should be according to the manual or Standard Operation Procedures (SOP). This misoperation causes the drilling mud fluid
contains coarse material and became abrasive since the screen of the circulating system was not so effective [5].

![Figure 3. Damage of wiper seal](image)

Rubber wiper seal condition is also getting worse. The fluid mud with coarse solid contamination entered the pump chamber through the gap of the seal leakages due to hot drilling fluid, the mud with solid contamination can enter the pump chamber through the scratched pump liner and the rubber piston that already washout because the abrasion from the contaminated fluid mud with high temperatures.

![Figure 4. Heavy scratches on liner (L) and piston rubber washout (R)](image)

![Figure 5. Clogged mud pump lube filter and lube line](image)
The contaminated drilling mud fluid flow in the power end of the pump is sucked by the lube pump, causing the pump's 3/8" line to clogged the lube pump, resulted in crosshead bearing being under lubricated and eventually caused it to break.

Further investigation revealed that non standard rubber seals were used, i.e. Nitrile Rubber seals, made of Butadiene Acrylonitrile rubber with temperature range of -40 °C to 121 °C. The installation is using these non standard rubber for components such as Lube pump rubber piston, wiper seal, liner seal, cover seals, valve insert seals, which all of them were washout. According to the Operation Manual and SOP for drilling operation on HPHT wells, all rubber components should use Viton rubber seals, made of Fluorinated Hydrocarbon rubber. Temperature range -23 °C to 315 °C [7].

3.4. Realistic probable root cause.
From the problems analysis based on data evidence, the sequences of damages that lead to failures due to drilling operation on HPHT well are as follows:
- Drilling mud fluid is getting heat inside the HPHT well and became hot when flowing back to the circulating system of the drilling rig. The mud fluid also bring out coarse materials from the drilling process in the bottom of the HPHT well.
- In the circulating systems, the mud fluid are supposed to be cooled down and cleaned up from coarse materials from the well before pumped back into the well [6]. Due to improper work and failed to follow SOP, the mud fluid that were sent back to the well were still hot dan contained coarse material.
- In the mud pump, it is revealed that un-standard wiper rubber seals are used. The un-standard seals made of rubber material that cannot hold the hot mud fluid with coarse materials inside it and then become washout. This is the failures root cause, due to disobeying SOP or Operation Manual.
- The washout wiper seals cannot hold the hot mud fluid from entering the lubrication pump and then destroying the lube rubber piston.
- As the lube pump fail, the mud fluid will be mixed with lube oil and entering the lubrication line. This makes the lube line clogged and the lube oil fail to lubricate the crosshead bearing.
- The un lubricated bearing will be burned due to metal to metal contact, and jammed the relative motions of the mechanical components, and finally it will stop working. Smoke from the heat generated will be the sign of an equipment failure.

4. Conclusion
1. Standard Operation Procedures (SOP) for complicated, sophisticated and expensive operation, e.g. oil and gas drilling operation, must be obeyed by every personnel to guarantee safety and proper work.
2. In Failure Analysis every data of failures must be collected and gathered, and then analyze the relevance and related data to see the connection among them. The failures root cause can be constructed from those informations.
3. Drilling operation comprise of various operations of soft to hard operation. Therefore, the materials in the drilling equipments are also of soft to hard materials. And in reality often a soft material failures can lead to a catastrophic failure, just like the failures of rubber seal in this case.
4. Changing equipment of soft material must be done very carefully since the materials are very similar to one another.
5. Damage that arises due to a particular problem can becomes more severe by the presence of other non-standard components such as screens component on the shale shaker equipment in the circulating systems so that the incoming coarse material size is still above the permitted size.
6. Mismatch between operating practices and standard operating procedures in well drilling with HPHT (High Pressure High Temperature) conditions causes damage to equipment components.
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