

Development of a One Trip Sidetracking System for Duplex 25% Chrome Casing

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Abstract

This paper describes the development of a new casing exit system capable of sidetracking through Duplex 25% Chrome casing. The CRA (Corrosion Resistant Alloy) casings generally have high chrome content and are deployed in wells associated with severely corrosive downhole environments. The CRA material tends to be abrasive to cutting tools due to several known phenomena such as work hardening, smearing, galling and welding. This negated the use of the standard sidetracking system to sidetrack through such casings. The economical redevelopment of such wells motivated the project of developing a casing exit system capable of sidetracking through chrome casings.

The performance of the standard sidetracking system in cutting chrome casing was analyzed in the initial development stages. The standard system was unable to cut open an initial hole in the chrome casing. Further testing confirmed a significant mill gage diameter wear which did not allow the system to qualify for a true one trip sidetracking system. With further improvements in the cutter type, interaction between the cutter and the casing, and other processes, a true one trip CRA sidetracking system was developed.

The developed mill and whip assembly with improved cutters was successfully tested and verified in a lab environment. The result of which was a 5-ft long, full-gage usable window, (3.80-in wide), cut in 5.5 hours, in a 5-in Duplex 25% chrome, CRA casing using a 3-7/8-in mill assembly. The test was conducted under standard operating guidelines. The gage diameter wear was within allowable acceptance criterion which qualified the developed system to be a true one trip sidetracking system for duplex 25% chrome casing.

Introduction

Sidetracking through casing is a specific application conducted to bypass an obstruction (fish), to re-use the existing well, to explore for additional producing horizons in adjacent sectors of the field, or to develop multiple wells from the existing borehole for economical development of a field, especially in offshore environments¹.

Casing sidetracks performed using a whipstock and mill assembly usually comprise of a whipstock having inclined ramps, and having an inclination of two to three degrees from the axis of the well and is permanently or temporarily set inside the existing casing. The mill attached to the lower end

of the bottomhole assembly (BHA) rides on the inclined whipface cutting an opening in the existing casing, and deviating the well trajectory, as the whipstock forces the mill into the casing wall thus cutting through the casing.^{1, 2, 3, 4}

The Corrosion Resistant Alloy (CRA) casings are used extensively in HPHT (High Pressure High Temperature) wells associated with severely corrosive downhole environments. The high concentrations of hydrogen Sulphide (H₂S) and carbon dioxide (CO₂) at elevated temperatures and pressures in the presence of oxygen (O₂) make the downhole environments severely corrosive for standard steel casings. The use of CRA material reduces the deterioration of the casings due to corrosion thus increasing the life of these wells.

The CRA casings are usually associated with a higher percentage of chrome content, and prove to be difficult in handling, especially while cutting and machining. The material tends to be extremely abrasive to cutting tools, as well as leading to work hardening, smearing, galling and welding. Furthermore, in cutting CRA casing, high asperity-junction temperatures are normal. The standard sidetracking system was not designed to account for most of the above listed factors which motivated the development of a whip and mill assembly capable of sidetracking through such casings for economical redevelopment of such wells. The scope of the project involved development of a sidetracking system to provide a 4-ft long usable window (3.80-in wide) in 5-in Duplex 25% chrome, CRA casing.

This paper describes the development of a One Trip sidetracking system, capable of sidetracking through Duplex 25% chrome, CRA casings. It reviews the modifications made in the sidetracking system to counter the problems observed during the design and testing phase of the project. It illustrates the results of the successful sidetracking test performed on Duplex 25% chrome, CRA casing, which qualified the mill and whipstock assembly to be a true one trip sidetracking system.

Overview of the Sidetracking Tool Development Process

Due to the difficulties in cutting and machining of the CRA casings as compared to standard steel casings, many tests using the standard sidetracking system were performed to determine and corroborate the problems associated with sidetracking through such casing. Relevant modifications were made in the sidetracking system and additional sidetracking tests were conducted to develop the system. Tests involving

the optimization of the modified sidetracking system were performed until it successfully sidetracked through the 5-in Duplex 25% chrome, CRA casings.

The product development process was completed in three phases. In the first phase, problems observed while conducting sidetracking tests, using standard systems were studied. It was found that mill assembly preferentially cuts the whipstock instead of cutting an opening in the chrome casing, defeating the entire purpose of the sidetrack operation. Phase II deals with finding a solution to the problem identified in Phase I. It was found that the cutter rake angles, stiffness of the mill assembly, whipstock hardness, and whipstock materials play important role in cutout capabilities of the mill assembly. While conducting further tests it was found that cutter wear on the mill assembly was significantly high which did not allow the sidetrack operation to complete in a single trip. Phase III of the project mainly dealt with assessing, modifying and testing the different factors like operating parameters, cutter type, and interaction between the cutter and the chrome casing to reduce the cutter wear until the system could successfully sidetrack through the 5-in Duplex 25% chrome CRA casing in a single trip.

Product Development Process

The development of the sidetracking system was completed in three phases as follows.

Phase I

Initial testing aided in the analysis and study of the standard system's performance in sidetracking through such casings. These tests were carried out in 5-in 23.2 #, Sumitomo SM25CRW-125 grade casings having 4-in ID. The tests confirmed that all the existing standard mill assemblies tend to preferentially cut the whip rather than cutting a window in the chrome casing. The modifications made to the mill and whipstock design were derived from the failure analysis of these tests. Pic 1 shows the wear on the whipstock face due to the mill preferentially cutting the whip.



Pic 1: Picture Depicting Preferential Wear of the Standard Whipstock in the Initial Tests

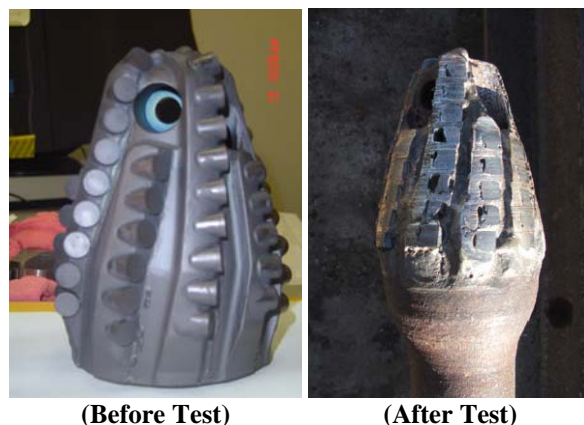
Phase II

Phase II of the project involved finding solutions to the problems observed in Phase I. In this phase many different parameters including the effects of changing the cutter rake angles, stiffness of the mill assembly, whipstock hardness, and whipstock materials were assessed and tested. During these

tests, it was found that all the aforementioned parameters played an important role in achieving a usable window, cut in the CRA casing.

While conducting further tests it was found that the mill wear rate was higher while cutting Duplex 25% chrome casings, than that observed while cutting standard steel casings. Also, it was found that after a certain cutter wear, the rate of penetration (ROP) reduces considerably below acceptable range, even before completing the sidetrack operation.

Pic 2 shows the extent of wear on the standard cutters on the mill assembly after extending the cut window for 4-ft in the 5-in Duplex 25% chrome, CRA casing. It compares the status of the cutters on the mill before and after the test.



Pic 2: Picture Depicting Mill Wear Before and After One of the Tool Development Tests.

The opening cut in the 5-in Duplex 25% chrome casing, is shown in Pic 3. It shows tapering of the window in the mid section. This tapering of the window width was caused mainly due to the mill and whipstock wear.



Pic 3: Window or Opening Cut in the 5-in Duplex 25% Chrome Casing by Mill Shown in Pic 2

Due to the requirements for a full gage window width in the mid-section of the window, a second mill run had to be made to ensure a 4-ft long full gage section measuring 3.80-in in width to complete this sidetrack operation. The second run would have contradicted the project's primary focus to develop a one trip sidetracking system. Phase III of the project focused on modifications to the cutter type, operating parameters, and interaction between the cutter and the CRA casing.

Phase III

As the project's primary focus was to develop a one trip

sidetracking system, a solution to the wear on the cutters observed on the mill assembly in the previous tests had to be found. Various cutter types were short-listed and tested for their performance in cutting 5-in Duplex 25% chrome casings. Along with the tests conducted using different cutter types, the effects of the interaction between cutters and casing as a function of the rake angles and milling parameters, rotary speeds, weight on bit (WOB), and torque requirements, were studied by conducting additional tests. New Inserts were selected based on the comparison of wear resistance numbers (ASTM B611 procedure) of the standard and new cutters, and wear rate predictions based on the observed cutter wear rates in the previous tests.

A cutter with higher wear resistance number was chosen for testing. This test proved successful in achieving our goal of cutting a 4-ft long full gage window (3.80-in wide), in the 5-in Duplex 25% chrome CRA casing in a single trip.

Details of the Successful Sidetracking Test

This successful sidetrack test was conducted to qualify the developed sidetracking system to be a true one trip system. The whipstock was set in 5-in, 23.2 # Duplex 25% chrome CRA casing, cemented in a 13 3/8" casing. The test was conducted using a 3 7/8" mill assembly. The results obtained were as follows:

- A 5-ft long window was cut in the 5-in Duplex 25% chrome casing. .
- The test was completed in less than 5 ½ hours.
- A 4-ft long usable window (3.80-in wide) was cut in the 5-in chrome casing suggesting minimal mill wear.
- The test was conducted using standard operating parameters.

Pic 4 shows the mill after completing this successful sidetracking test. Pic 5 shows the window or the opening cut successfully in the 5-in, 23.2# Duplex 25% chrome CRA casing by mill shown in Pic 4.



Pic 4: Picture Depicting Mill Wear After successfully Sidetracking through Duplex 25% Chrome CRA Casing in One Trip



Pic 5: 5-ft Long Window or Opening Cut in 5-in, 23.2# Duplex 25% Chrome Casing by Mill Shown in Pic 4

Conclusions

The developed sidetracking system was successful in meeting the remit of the project which was to cut a 4-ft long usable window (3.80-in wide) utilizing standard operating parameters in a single trip through Duplex 25% chrome CRA casing.

Acknowledgments

The authors humbly appreciate the support of all the Engineering, Operations, Manufacturing and Test personnel for their valuable contributions during the different phases of the project.

Nomenclature

CRA	= Corrosion Resistant Alloy
BHA	= Bottomhole Assembly
ROP	= Rate of Penetration, ft/hr
WOB	= Weight on Bit, lbs
OD	= Outer Diameter, in
ID	= Inner Diameter, in
HPHT	= High Pressure High Temperature

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