SPE 110804

Life of Well Isolation Implemented in Major North Sea Development

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This paper was prepared for presentation at the 2007 SPE Annual Technical Conference and Exhibition held in Anaheim, California, U.S.A., 11–14 November 2007.

Abstract

The Buzzard field operated by Nexen is the largest oil discovery in the North Sea since the early 1990s. About 27 production wells, of approximately 9,000 ft total vertical depth (TVD), will be drilled during the field life. Maximized life of well isolation is imperative. The production liners are being cemented with a life-of-well engineered solution.

The reservoir section consists of two discrete oil-bearing sandstones. Oil recovery will be maximized by water injection from subsea wells. Isolation of the production sands enhance management of the waterflood and thus maximize the producible volume. The challenge was to develop a cement system that could achieve and maintain isolation throughout the life of the field.

A finite element-based analysis tool was used to build a model of the reservoir section. The model was then used to predict the forces on the cement sheath throughout its life under all load conditions, including those caused by pressure and thermal changes during drilling, completion, and sustained production.

The model predicted that a conventional cement sheath could fail in three modes: debonding at the formation, compressive shear, and radial cracking. A cement sheath with lower Young's modulus, higher tensile strength, and shrinkage compensation was required. A series of designs were tested to select the optimum solution that met the life-of-well needs.

The successful implementation of this new approach to cementing required special planning and organization. To date, 13 wells have been cemented with the life-of-well solution, with no operational problems and indication of good placement.

Bond-log results differ from those expected from conventional slurries because of elastic components in the life-of-well slurry. Special data processing techniques have been developed to allow evaluation using conventional bond logs; these are presented in this paper.

Analysis, design, and field implementation discussed in this paper can be applied to field development in other locations where zonal isolation during the well life is critical.

Introduction

The costs of lost production and workover rates caused by medium and long-term cement failure are massive. It was an economic necessity to address this condition in recent developments in the North Sea, the Nexen Buzzard field. Twenty-seven production liners are being cemented with a solution engineered for the life of well. This paper describes how modern finite element analysis (FEA) technology was used to design a cement sheath fit for long-term purpose in Buzzard, how it was tested, and how it is being implemented successfully.

Industry Background

Cement sheath failure is manifested in early water production, sustained casing pressures, and interzonal communication. These failures lead to high-expenditure remedial work, reduced production, and even catastrophic failure, such as casing collapse, which can jeopardize the safety of the entire well. The industry has long suffered from these failures but has not known how to adequately address them.

In the past, an isolation problem, subsequently revealed, has simply been attributed to a poor cement job without understanding that the cement may well have been placed properly, however, a failure nevertheless occurred because of inadequate mechanical properties of the in-situ cement sheath.

The way we view primary cementation is changing. We are expanding our understanding and our ability to predict how a correctly placed cement sheath will behave under the stresses experienced during the whole life-of-well. As soon as the cement begins to gain compressive strength, it is subject to strain. It is important to investigate the resultant stresses in the critical phases throughout the life-of-well. If these stresses exceed the endurance limit of the cement sheath then either tensile or shear failure can lead to cracking or debonding from the formation or casing and lead to formation of a microannulus. The following are critical phases where these can occur:

Hydration. While setting, the cement can shrink substantially, leading to tensile cracking and formation of microannuli.

Pressure testing. Applied pressure causes the casing to expand, which compresses the cement before the casing relaxes and potentially debonds.