Creating operator value by maintaining cement integrity for the life of a well

Axel-Pierre Bois, Greg Galdiolo, Anthony Badalamenti, CURISTEC

Abstract

Today more than ever oil and gas producers are being measured by governmental and financial institutions in the areas of well safety and return on investments.

Obtaining and maintaining cement sheath integrity for the life of the well is an essential component in ensuring the safe and efficient harvesting of hydrocarbons. Additionally cement sheath integrity can directly impact the financial viability of a single well or an entire production field.

Over the years the oil and gas industry and various governments have dedicated countless research and development dollars in the study of oil well cementing. In the past 15 years, one of the key areas of cementing research has focused on cement integrity for the life of the well.

This white paper briefly discusses how cement sheath integrity directly impacts both the safety and financial performance of a well or project. Additionally it shows how new technologies in the areas of cement integrity modeling and laboratory-testing methods are enhancing the ability to achieve cement integrity for the life of the well.

Background

The main objective for oil well cementing is well integrity. The 12th edition of the IADC Drilling Manual states, "*The principles and processes for establishing and maintaining cement as a barrier are central to providing well integrity*". Establishing a successful cement barrier is hard and maintaining a complete cement barrier for the life of the well is even harder.

There are a multitude of well events that can damage a cement barrier; they include loads due to temperature and pressure changes, well stimulation programs, formation compaction, and cement degradation. A damaged cement barrier can result in well problems associated with loss of reserves due to inner-zonal flow, early water breakthrough, steam and water injection out of zone and sustained casing pressure. All of these problems increase the daily operating cost of the well and can lead to well safety or regulatory issues.

Repairing a damaged cement barrier is expensive, technically challenging and typically requires a well work-over and re-completion programs. In some instances a damaged cement barrier cannot be repaired, which can lead to either expensive well safety monitoring programs or early well abandonment.

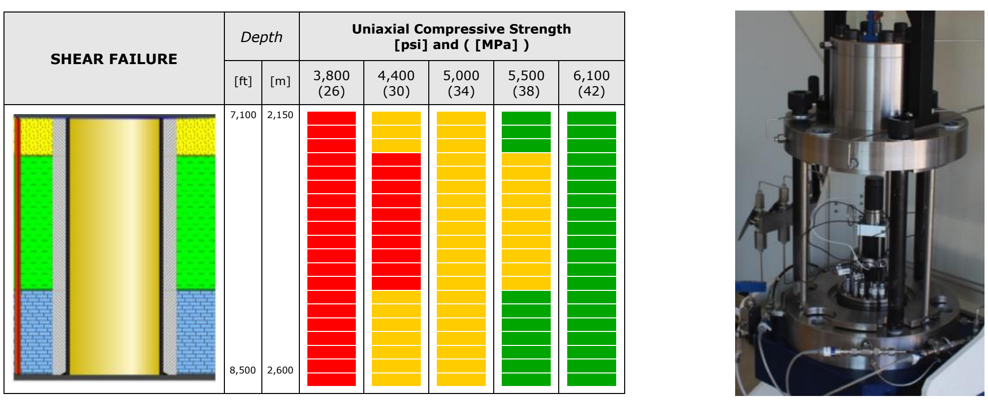
Solution

In order to establish and maintain a successful cement barrier for the life of a well, there are four critical steps that should be mastered in the cement sheath design process.

- Step one: Quick look risk analysis
  During the well planning stage a Quick Look cement simulation enables the operator's wells team to quickly identify the risk and mode of cement sheath failure for conventional and advanced cement designs. Many times a Quick Look cement simulation may indicate potential well design changes that the wells team can easily implement that may reduce the risk of cement sheath ability failure. Additionally, cement sheath design engineers can use a Quick Look cement simulation to identify if advanced cement integrity modeling is required and the correct cement model to use therefore reducing modeling and laboratory testing time.

- Step two: Cement system design (Figure 1)
  The cement sheath must be designed to withstand the anticipated stresses that it will be subjected to during the life of the well. In the past fifteen years, new cementing design tools such as cement mechanical integrity models and triaxial load cell testing have been incorporated into the cement designing process.

  Experienced cement design engineers use cement mechanical integrity (CMI) models to study how changes in wellbore pressures, temperatures and reservoir compaction affect the cement sheath and analyze if the cement design can successfully withstand these events. Many times the engineers use CMI models to identify the required cement mechanical properties before beginning to design the cement slurry. Once the CMI modeling is completed and the cement sheath is designed, triaxial load cell testing is performed to ensure that the cement design mechanically performs as required. In addition to the standard mechanical testing for Young's Modulus and Poisson's Ratio, many times cement expansion, cohesion and friction angle test are also performed.



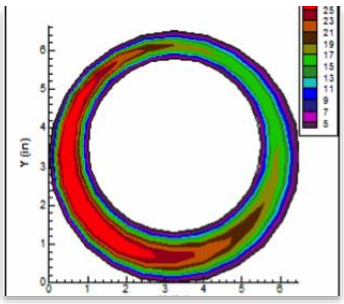
CMI modeling to evaluate the impact of uniaxial compressive strength on cement sheath integrity

Triaxial load cell to evaluate cement mechanical properties

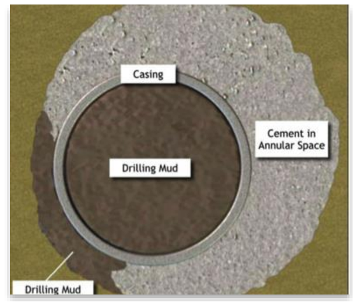
Figure 1. Use of CMI modeling and triaxial mechanical testing to ensure cement-sheath integrity

- Step three: Cement slurry placement (Figure 2)
  The designed cement slurry must be safely placed into the wellbore-casing annulus to obtain complete radial coverage and prevent fluid flow during hydration. To meet these objectives the cement design engineer uses a primary cementing job simulator that may include dynamic temperature models, casing centralization models, fluid flow models and 3D hydraulic simulators based on computational fluid dynamics (CFD). These tools are targeted at achieving a higher order of cement placement in the annulus and preventing cement channels caused by either cement placement or fluid

flow through the cement slurry during setting. To ensure that the cement design can be safely placed in the well, conventional cement laboratory testing are performed. These test include, total thickening time, rheology compressive strength, free fluid, fluid loss, gel strength development and well fluid compatibility.



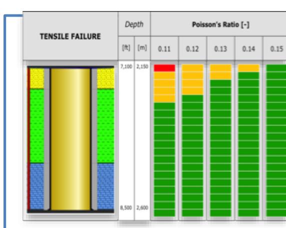
Example of Cement Slurry Placement Simulation



Example of Mud Channel Related to Tubular Eccentricity

Figure 2. Use of CFD modeling and example of the consequence of poor displacement of mud from the annulus

- Step four: Quality assurance / Quality control (Figure 3)
  Cement sheath design validation and quality assurance laboratory testing is typically performed once the cement design has been blended and prior to being delivered to the well site. Typically quality assurance testing includes both conventional and triaxial load cell cement testing, and helps ensure that job problems do not occur and that the blended cement meets the mechanical performance requirements.



Cement Design Validation

QA Conventional Testing

QA Tri-Axial Testing

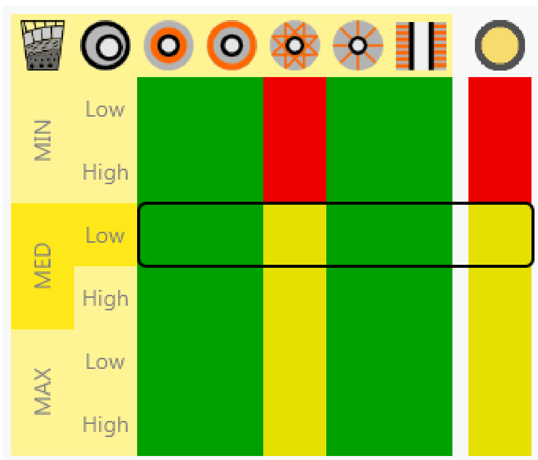
Figure 3. QA/QC steps

Meeting the industry's challenge

CURISTEC is a privately owned industry recognized technology company, specializing in oil & gas geomechanics, wellbore integrity, cement integrity, materials testing, engineering software and consulting services. Below are two of CURISTEC's cementing products and services (Figure 4)

CurisIntegrity is CURISTEC's flagship cement mechanical integrity software. It enables the engineer to quickly and easily evaluate five modes of cement sheath failure using multiple loadings from temperature, pressure and cement hydration. CurisIntegrity can also determine the cement sheath's mechanical properties requirements to prevent cement damage throughout the life of the well.

CurisLab is CURISTEC's rock and cement testing laboratory located in Pau, France. It maintains an ISO-9001 certification, is staffed by skilled engineers that are experts in not only oil well cement testing but also have cementing experiences in research and development, field operations, and engineering. Their multi-tiered cementing experience enables our staff to test and analyze all facets of cement testing.



CurisIntegrity synthesis output: failure damage versus casing standoff and formation stiffness

CURISTEC ISO9001 certified laboratory with HTHP cement consistometers

Figure 4. Two of CURISTEC's cementing products and services

Conclusion

Today more than ever, oil and gas producers are focused on well safety and achieving project return on investment expectations. Cement barriers are essential to ensuring well integrity because damaged cement barriers can result in well safety issues and increased daily operating cost.

Establishing and maintaining a cement barrier for the life of a well is hard and requires a holistic engineering approach that includes:

- Cement mechanical integrity modeling
- Conventional primary cement job modeling
- Implementation of new cementing technologies
- Laboratory testing for cement sheath design and quality assurance.

CURISTEC is leading the oil and gas industry in cement integrity modeling and cement mechanical property testing and is well positioned to meet your cement engineering and cement testing needs. Please visit our website (www.curistec.com) to find out more about CURISTEC, its products, services and contact information.