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Characterization of Cement Systems to Ensure Cement Sheath Integrity

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Abstract

In drilling wells, zonal isolation is provided by cement sheaths. To maintain a good integrity to these cement barriers, it is recommended to optimize the placement of the fluids and thus the mud removal in the wellbore. It means that cement slurry properties like mixability, stability, rheology, fluid loss, and thickening time, should be taken into account. However, the cement slurry will move forward up to the next step, which is the setting and the development of its mechanical properties.

Characterization of set cements is normally provided by running specific tests like compressive strength determination by crushing cement specimens or by sonic measurement with Ultrasonic Cement Analyzer (UCA) equipment. Other tests can also be run to highlight specific properties, i.e. porosity, permeability test.

Aiming at being able to account for the changes that occur in the wellbore, for example an increase or a decrease in fluid density or in temperature, perforations, etc., Total has developed a new software, SealWell©, to simulate and/or anticipate the possible consequences of these changes. Hence, Total is able to evaluate which specific mechanical properties (Young's modulus, Poisson's ratio, tensile strength…) values are required for a cement to withstand the various encountered stresses, and to ensure a good zonal isolation and cement sheath integrity for the whole history of the well.

Experiments performed in the laboratory show that compressive strength determination by crushing specimens as describe in API specifications 10A[1] or 10B-2[2] (identical to ISO 10426-1 and ISO 10426-2) or even by using sonic measurements cannot be used as a stand-alone to fully characterize mechanical cement properties. That is why Total has developed a methodology based on SealWell© software and specific tests previously optimized to characterize rocks, which allows designing new cements that can be described as resilient or cements with improved mechanical properties. This methodology was validated when used to design resilient cements for field applications in the North Sea.

Introduction

Loss of well integrity can have multiple consequences from major ones (cross flow, pressurized annulus, well control situation) to catastrophic ones (blow out, infrastructure damage), impacting OPEX as well as CAPEX. Well integrity is a criticial point that Operators must properly handle during the whole life of the well. It requires good engineering and operating practices, especially when wells are challenging with sharper engineering combined with severe local authorities' requirements.

During its life, the well has to cope with different stresses and temperature. To preserve its integrity, casings as cement sheaths have to present adequate mechanical properties. Although this is well known when selecting a casing, it is not a common practice when designing a cement sheath. Once designed and the formulations chosen, lab tests have to be performed to determine the cement mechanical properties. Different techniques are available to determine either the compressive strength, tensile strength, Young's modulus or Poisson's ratio. However, when used, the pros and cons of these techniques must be known to understand the results before using them as input.

Total present here the result of a study performed on these different techniques following the development of SealWell©, a new software dedicated to the design of cement sheaths, motivated by years of expertise in rock mechanics. Guidelines were issued from these results. They were successfully applied to ensure the integrity of a well presenting a high-pressure anomaly.

Accuracy of cement slurry characterization

The challenge for primary cementing operations is to have a competent seal between the casing and the formation. Competent, in this case, means that the cementicious material should withstand the various stresses occuring during the life of the well. However, when designing a cement, it must be remembered that before being a solid barrier, a cement is a liquid that must be pumped and placed.

To design this fluid, parameters from the well (temperature, pressure, type of formation, fluids in the well, etc.) have to be measured or estimated. With this information, cement properties can be designed and basic rules must be followed, for instance the density of the slurry has to be defined according to the pore and frac pressures. This density