Use of Finite Element Analysis to Engineer the Cement Sheath for Production Operations

Abstract
Many successfully cemented wells begin to show annulus pressure buildup, which is often caused by damage to the cement sheath integrity from post-cementing operations. This problem may be temporarily dealt with by releasing the annulus pressure. However, this method of annular gas production is not a long-term solution to the problem.

A finite element analysis (FEA) method has been developed to analyze the effects of various well events and operations such as cement hydration, casing pressure testing, completions, and production on the integrity of cement sheath during the life of the well. The four-dimensional FEA modeling considers the sheath’s mechanical properties, such as Young’s modulus, Poisson’s ratio, and tensile strength, in addition to confined compressive strength, and helps provide the user with a cement design that can maintain an annular seal over the life of the well.

This paper discusses how a cementing design specialist can model the events upon and after cement placement to help provide a long-term seal of the annulus. The required input data is discussed, and the output information is shown for example wells.

Life of the Well
The main purpose of the annular cement is to provide effective zonal isolation for the life of the well so that oil and gas can be produced safely and economically. To achieve this objective, the drilling fluid should be removed from both the wide and narrow annulus, and the entire annulus should be filled with competent cement. The cement should meet both the short-term and long-term requirements imposed by the operational regime of the well.

Traditionally, the industry has concentrated on the short-term properties that are applicable when the cement is still in slurry form. This effort is necessary and important for effective cement-slurry mixing and placement. However, the long-term integrity of cement depends on the mechanical properties of the cement sheath, such as Young’s modulus, tensile strength, and resistance to downhole chemical attack. Considering properties of the cement sheath for long-term integrity is critical if the well is subjected to common changes in the pressure and temperature of the cased well.

After cement is placed in the annulus, if no fluid immediately migrates to the surface, short-term properties such as density, rate of static gel strength development, and fluid loss of the cement may have been designed satisfactorily. However, recent experience has shown that after well operations such as cement hydration, casing pressure testing, completions, and production, the cement sheath could lose its capabilities to provide zonal isolation. This failure can create a path for formation fluids to enter the annulus, which pressurizes the well’s annulus and could render the well unsafe to operate. The failure can also result in premature water production that can limit the economic life of the well.

Failure of the cement sheath is most often caused by pressure- or temperature-induced stresses inherent in well operations. Loss of isolation can shorten or destroy the life of the well because of corrosive-fluid attack on the casing and cement sheath and/or sustained gas pressure on the casing annulus.
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A finite element analysis (FEA) method has been developed to analyze the effects of various well events and operations such as cement hydration, casing pressure testing, completions and production on the integrity of the cement sheath during the life of the well. The three-dimensional FEA modeling considers the sheath's mechanical properties, such as Young's modulus, Poisson's ratio and tensile strength, in addition to confined compressive strength, and helps provide the user with a cement design that can maintain an annular seal over the life of the well. This paper discusses h