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Prediction of stress distributions in eccentric wellbores: Analytical and Numerical Modeling

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ABSTRACT

Primary well cementing is the process of placing a cement slurry into the annular space between the steel casing and surrounding geological formation. Primary cementing not only provides structural support but also offers casing protection, isolating aquifers and other fluid bearing formations from one another. Maintaining the well integrity is vital throughout the entire lifespan of wells, including when decommissioned. Mechanical failure of the cement sheath within the wellbore is influenced by many factors including the wellbore's geometrical properties. Geometrical irregularities such as eccentricity of the casing in the borehole and non-circular shape of the borehole can significantly affect well integrity.

Geometrical irregularities can result from combination of geology, drilling and/or completion operations. Eccentricity of annuli commonly occurs in real-world drilling operations, particularly in horizontal wells. During the drilling process, the change of the inclination and azimuth of the wellbore may cause eccentricity within annulus. Annulus eccentricity further affects the stress distribution within the cement sheath. It has been demonstrated that annulus eccentricity could significantly increase the stresses of well cement at the narrow edge of annulus which can lead to various mechanical failure modes within wellbore. Small cracks and interfacial debonding can create interconnected pathways along the well and allow formation brines to contact and corrode the steel casing, leading environmental problems such as contamination of freshwater table, leakage in aged wells, and the need for extensive/expensive remedial work.

There is currently no analytical model that addresses the influence of annulus eccentricity on stress distribution within a wellbore during the curing process, and numerical modeling is typically time-consuming for long wells. This study aims to develop an analytical model to predict evolution of stresses in the well cement sheath within the eccentric annulus during curing time. Developing such a model would significantly enhance the understanding of wellbore stress dynamics under annulus eccentricity. For this purpose, the equivalent perturbed domain solution has been employed to estimate the stresses in eccentric wellbores. The third-order boundary perturbation method has been adapted and developed for this model, considering both inner and outer pressures to meet the specific requirements of the wellbore system. To ensure the accuracy and relevance of our model to practice, a numerical model is also developed. Analytical results are compared with those obtained numerically for concentric and eccentric wells. This investigation offers valuable insights into the effect of wellbore eccentricity on stress distribution within annulus throughout the curing process.