Experimental Analysis of Cyclic Loading Effect on Seal Integrity of Cement Sheath

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The cement sheath is the first barrier of well integrity, and plays a critical role in maintaining the zonal isolation and ensuring the safety of oil and gas wells. Once the cement sheath seal fails, it will lead to issues such as fluid leakage and sustained casing pressure. Cyclic loading will cause cumulative plastic strain and strength degradation of cement stone, which is a relatively dangerous working condition for the downhole cement sheath. In this research, the laboratory experiment method was used to carry out the seal integrity test under cyclic loading on the cement system with conventional density (1.9g/cm^3). X-ray CT scanning was performed on the cement sheath sample after the test to observe the form of sealing failure. The research shows that the failure modes of the cement sheath under cyclic loading are mainly interface debonding and tensile cracks. After the internal pressure of the casing was loaded to the upper limit for the first time, the gas channeling flow was monitored, indicating that the cement sheath had lost its sealing performance. After that, the gas flow rate gradually increased with each additional cycle. Under multiple cycles, the cement sheath is compacted and its deformation capacity is weakened. Due to the accumulated plastic deformation, micro-annulus is generated at the casing-cement sheath interface. The cyclic loading also caused multiple cracks in the cement sheath sample, including penetrating cracks from the bulk to the interface. This research also pointed out that the modification direction of the cement system should be to improve the deformation capacity and strength of the cement sheath, which can reduce the risk of seal integrity failure. The research results are beneficial to understand the influence of cyclic loading on cement sheath and guide the design of cement sheath system.

Key words: Cyclic loading; Cement sheath; Seal integrity; Interface debonding; Tensile cracks