Laboratory study on low temperature early strength toughness self-healing cement slurry

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ABSTRACT

Salt cavern gas storages have the problems of shallow burial, low temperature, high requirements for low temperature early strength performance, salt resistance performance of cement slurry and sealing integrity under alternating load of cement sheath. A new cement slurry system was formed by optimizing the key additives such as salt-resistant early strength fluid loss additive, strength enhancing agent and self-healing agent, called low temperature early strength toughness self-healing cement slurry system. The performance evaluation experiment shows that the cement slurry system has the advantages of rapid development of low temperature strength (strength development at 52 °C for 6 hours), good comprehensive performance (meet the requirements of field cementing construction), excellent mechanical properties (compressive strength 33.27 MPa and Young's modulus 5.65 GPa for 7 days), and good sealing integrity of cement sheath under alternating load conditions (no damage occurred after 50 cycles under the condition of confining pressure of 28 MPa, alternating internal pressure of 4~24 MPa and alternating temperature of 50~65 °C), which can ensure the long-term sealing integrity of salt cavern gas storage.

KEY WORDS: Salt cavern, gas storage, cement slurry, low temperature early strength, toughness self-healing.

INTRODUCTION

Sealing performance of salt cavern cavity and wellbore is the key to long-term efficient operation of salt cavern gas storages (Yuan, 2008). Cementing quality is the most important factor to ensure wellbore sealing.

The salt layer of salt cavern gas storage is shallow and always with low formation temperature (maximum 60 °C). The highest temperature in the well is generally about 50 °C during normal cementing operations, and it will be lower in winter. For saltwater cement slurry system, has the problems such as poor stability at low temperature, difficult to control fluid loss, slow development of compressive strength, strong thixotropy, poor rheology and so on. These will make cementing quality difficult to guarantee (Qin, 2015; Zhu, 2006). At the same time, salt cavern gas storage has large gas injection and production, and the wellbore is under alternating stress state. During the service life of salt cavern gas storages, alternating stress must be considered to ensure the safe operation of gas storage for at least 30 years (Ding, 2010; Li, 2012; Li, 2010). Therefore, to ensure the long-term safe operation of gas storages, the stability of cement sheath strength and long-term sealing performance must be guaranteed.

By optimizing the key additives such as salt-resistant early strength fluid loss additive JSS, toughening agent BCE-310S and self-healing agent BCY-201S, the salt-resistant low-temperature early strength and toughness self-healing cement slurry system for cementing of salt cavern gas storage was formed. The mechanical properties of the cement sheath met the requirements of SY-T 7648-2021 Gas Storage Well Cementing Technical Requirements. The cement sheath has no damage after 50 times of operation under confining pressure of 28 MPa, alternating internal pressure of 4~24 MPa, and alternating temperature of 50~65 °C, which can ensure the long-term sealing integrity of salt cavern gas storages.

EXPERIMENT

Geological engineering overview

Taking Zhangxing salt cavern gas storage, Jiangsu Province, China, for example. The strata encountered from top to bottom in this block were: Quaternary Dongtai Formation, Tertiary Yancheng Formation and Cretaceous Pukou Formation. In the second section, Φ311.2mm drill bit and Φ244.5mm production casing were used to seal the salt layer for 30m, which required high initial cementing quality and long-term integrity of cement sheath. The strata temperature of this block was 65 °C, the circulation temperature was 52 °C, the strata pressure was 23 MPa, the density of used cement slurry was 1.90g/cm³, and the designed operating pressure of this gas storage was 11.5~28 MPa.

Design idea of cement slurry

Construction performance