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The development of self-healing cement for the remediation of cracks and micro-annuli in oilwell cement sheaths

microbially driven $CaCO_3$ precipitation for *in-situ* repair of cracks in cement

Fabian Steinacher[1], Shuai Nie[2], Pablo Alberdi-Pagola[3], Jørgen Skibsted[2], Hans Røy[1], Gregor Fischer[3] and Kasper U. Kjeldsen[1]

[1] Department of Biology, Section for Microbiology, Aarhus University, Denmark

[2] Department for Chemistry and Interdisciplinary Nanoscience Center (iNANO), Aarhus University, Denmark

[3] Department of Civil and Mechanical Engineering Structures and Safety, DTU, Kgs. Lyngby, Denmark

Worldwide, the oil and gas industry is suffering from substantial number of well integrity issues due to compromised well cement sheaths and sustained casing pressure. One of the key challenges in oilwell cementing is the formation of cracks in the cement matrix and at the bonding interfaces rock/cement, cement/casing due to restrained shrinkage and pressure and temperature variations. Here cracks and micro-annuli could lead to fluid leakage migration pathways over time and compromise the integrity of the constructed wellbore.

Crack evolution in a time-series in a real rock/cement/casing composite were measured via digital image correlation technique. From there cracks and debonding at the interfaces could be quantified and based on this a single crack experiment was designed with the purpose to induce cracks from 120-200 microns in a controlled manner. On the other side, the development of bio-active self-healing cement was pursuit to apply this technology system for calcium carbonate precipitation and thus crack healing in oilwell cement. Our aim was to investigate the survival and activity of bacterial-endospores in high pH environments and their germination efficiency and resultant cell growth in carriers used in bio-active cement. Endospores were impregnated in lightweight expanded clay aggregates, were tested, and optimized, for supporting endospore survival and growth along with the effect of the carriers on the mechanical properties of the oilwell cement.

Key findings of the bio-active self-healing cement with embedded lightweight expanded clay particles were demonstrating promising results, including micro-crack filling with the bio-mineral calcium carbonate grown from the cement paste being observed both by optical light-microscopy and scanning electron microscopy at different scales; non-destructive micro x-ray computed tomography could visualize for the first time the crack self-healing repairing phenomenon at sub-micron scale. Permeability tests on specimens with controlled single cracks with a width ranging from 120 to 190 µm were established and the self-healing potential with an own developed cement curing and self-healing workflow evaluated. The bio-active self-healing cement formulation was able to heal through the fracture plane and could reduce permeabilities substantially.

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