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Electrophoresis to improve cement-steel bonding in well construction

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After production, all wells need to be permanently plugged and abandoned (P&A'ed). Long-term well integrity will then rely on the integrity of cement, which is the material typically used for permanent well plugging and for filling the annular spaces between casing/rock. The cement is pumped into the well as a slurry, and hardens to form mechanical and hydraulic seals. Cement has proven to be a robust material for subsurface constructions, but concerns are directed towards the interfaces between cement/rock and cement/casing. These are prone to delamination (commonly referred to as "debonding") and can thus act as leakage paths for formation fluids (oil, water, gas) along the well. In order to reduce the long-term environmental impact of oil and gas production activities, it is thus necessary to improve this "weak link" of today's well construction.

Bonding between cement and steel is controlled by the material structure and packing in the interfacial transition zone (ITZ), a thin (50-100 micron wide) zone located in cement near the steel surface. Applying positive potential on the steel wall improves the bonding and thus could be used to improve long-term well integrity in the field. In downhole conditions, however, cements are subject to elevated pressure and temperature. Moreover, composition of well cements is usually designed so as to stabilize the slurry and thus to reduce attractive forces between the particles. These operational factors may adversely affect the efficiency of such eletrophoresis-induced bonding enhancement.

Experiments are performed in order to investigate the effect of different operational factors (ionic strength, zeta-potential, particle size distribution, additives in cement) on the electrophoresis-induced bonding enhancement. A mesoscopic particle-based model is constructed and used to study the effect of operational factors on the process. The model is based on the discrete-element method (DEM) where particle interactions are introduced via the lubrication force. The lubrication accounts for, in general, non-Newtonian rheology of the carrier fluid in the cement slurry. Stokes flow is assumed. The model enables two-way coupling between the electric field and the particles. It also accounts for the effect of electrolysis near anode upon the particles.

References

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