Qualifying Geothermal Applications for Fouling Repellent Sol-Gel Coatings with a Proven Track Record in the Offshore Oil Industry

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Introduction

To be competitive and reduce costs, geothermal operators must pay attention to proper maintenance of critical equipment, especially the heat exchangers (HX's) transferring heat from the geofluid to the working fluid. To overcome these issues the geothermal sector should pursue collaborations with other industries to identify crossover technological solutions. Crude oil fouling of plate heat exchangers (PHE's) is a very common and major challenge for operators in the offshore oil industry. Oil repellent sol-gel coatings from Danish Technological Institute (DTI) have for a number of years proved to solve these fouling issues.

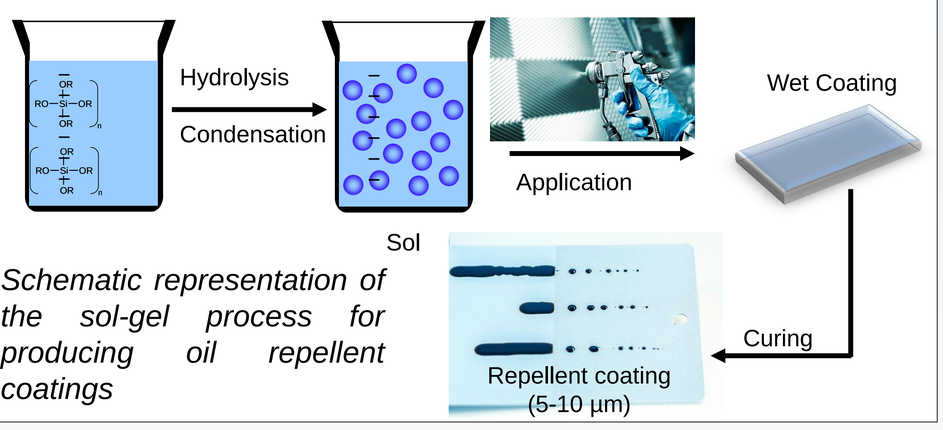
Aim

Verifying potential technological crossover opportunities by upgrading the corrosion resistance of oil repellent sol-gel coatings, initially developed for the offshore oil industry, and test performance in laboratory conditions that mimic those for HX's in geothermal installations.

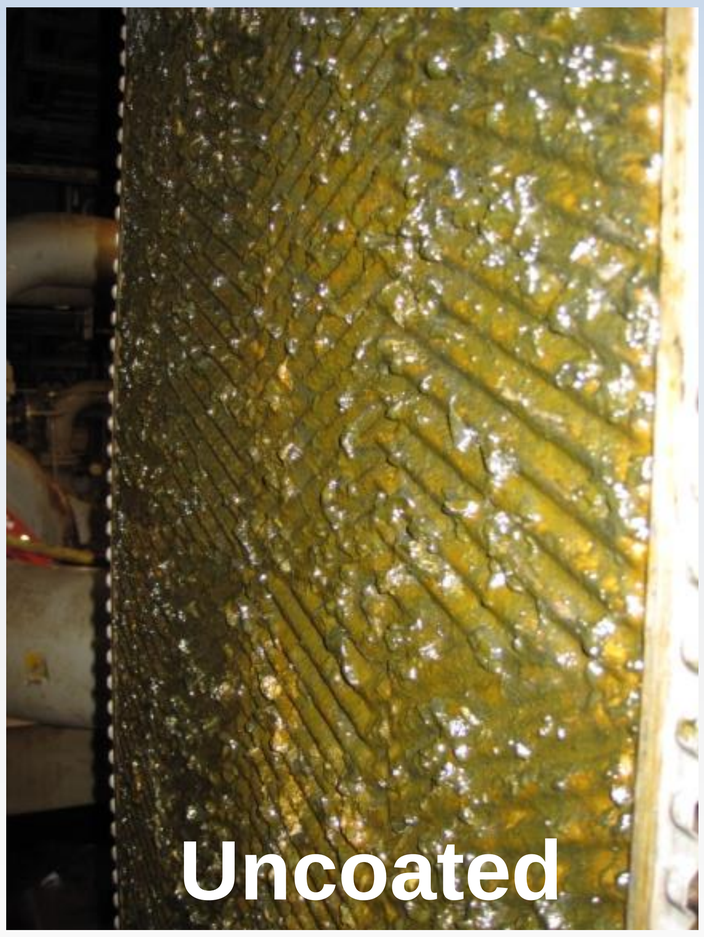
Geothermal site of Balmatt (Be)

Offshore Crude Oil Fouling Mitigation

Oil repellent sol-gel coatings have proved to be a cost-effective solution for PHE's to maintain clean heat-transfer surfaces during operation. The coatings are commercially available and have, for a number of years, been utilised on PHE's in the North Sea. Service time for coated PHE units are at least 3 years* whereas uncoated units typically last 6 months if costly and regular maintenance and cleaning procedures such as hot-runs, chemical treatment and onshore cleaning and refurbishment are not preformed.



Schematic representation of the sol-gel process for producing oil repellent coatings



**Due to fatigue cracking of the plates service operation was stopped . Comparison between a coated (left) and uncoated (right) PHE plate after 7 months of operation*

Qualifying for Geothermal Applications

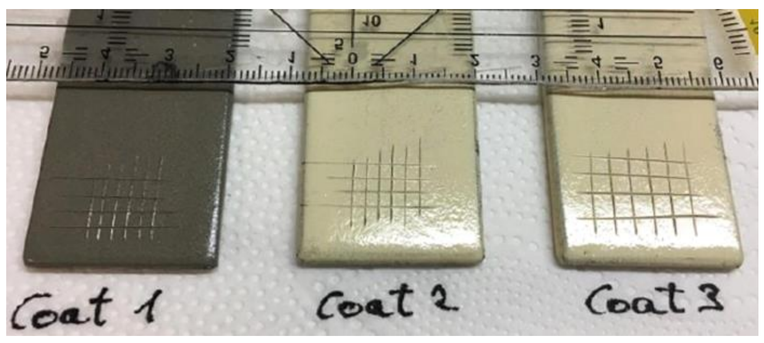
In MATChING** (H2020), the corrosion resistance of repellent DTI sol-gel coatings were upgraded using a multilayer coating approach. These multilayer coating systems consist of a sequence of 3 coatings (one primer and two intermediate layers) and a repellent sol-gel topcoat. The coating thicknesses were optimized to provide optimal corrosion protection, repellency and heat transfer.

Testing and Evaluation

	Lab test (LOTU)	In situ Balmatt	
Temperature	125-135 °C	125-135 °C	
Pressure	30-40 bar	~ 40 bar	
Partial pres. of CO_2	-	CO2 in gas mix	76.5 vol %
pH	5.55	~ 5.55	
Stirring	600 rpm	Flow rate	100-200 m^3/h
Exposure time	~24 days (570 h)	Flow vel.	1 m/s

Custom-designed device (LOTU) for evaluating coating performance

The integrity of the coatings after exposure was assessed visually (rusting, blistering) and by testing adhesion.



Results

Parameter	Coating
Adhesion rating	0
σ (mN/m)	25
Blister	None
Rust	0
Comment	Pass

A number of coating combinations retained excellent adhesion, had a very smooth surface without visual damage and very low surface energy (S.E.). Smoothness and low S.E. are key aspects in heat exchangers for reducing tube wall friction and improving the overall heat transfer.

Calculated heat transference and thermal resistance

	Thickness (µm)	Thermal conductivity (W/m K)	Thermal resistance (m^2K/W)
Coat	250	~ 0.63	0.0004

Geothermal HX's are typically designed with a fouling factor on the brine side (Rf) of 0.0004 m^2K/W. The coatings impact the thermal resistance by a similar factor but prevent corrosion and fouling.

Conclusion

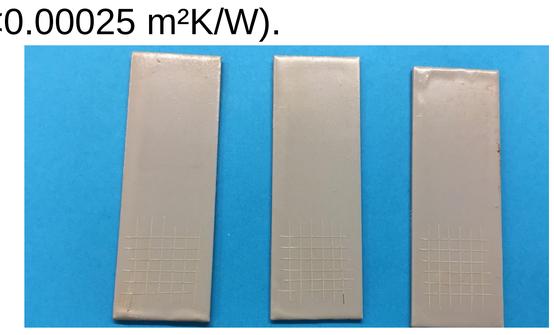
Several potential coating combinations show promise based on laboratory test conditions mimicking the Balmatt geothermal site. Currently ongoing tests in the frame of MATChING are investigating whether the laboratory tests correlate well with the field performance.

Further Developments

To reduce the total thickness coating systems have been made with:

- inorganic primer (< 1 µm)
- single intermediate coating (120 -150 µm)
- sol-gel topcoat (5-10 µm).

To increase heat transfer and corrosion resistance aluminum flakes are incorporated into the intermediate coating (total thickness 130-160 µm, Rf<0.00025 m^2K/W).



Tested 17 days 3.5 % NaCl (aq) at 90 ºC

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