The GeoHex Project: Anticorrosive coatings for geothermal heat exchangers

The GeoHex Project is funded by the European Commission under the Horizon 2020 programme, Grant agreement 851917. Initially kicked off in November 2019, GeoHex is led by a consortium of partners across Europe, and includes one partner in the Philippines. The project intends to improve and enhance the use of heat exchangers in geothermal energy production.

By Ellie Pritchard

I spoke with project leader and coordinator, Namrata Kale, and metallurgist Imran Bhamji, who acts as technical lead on the GeoHex project. Both Namrata and Imran work for global company TWI, an independent research and technology organisation specialising in materials performance, structural integrity and joining.

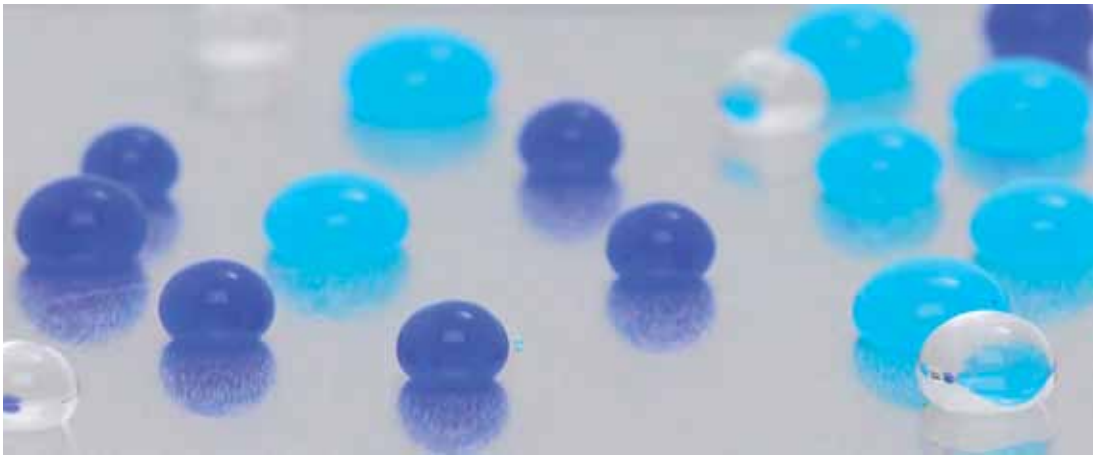
The challenge of geothermal

At present, multiple challenges face heat exchangers in geothermal applications. "The technical scope of the project is looking at coatings for heat exchangers to improve heat transfer, scaling and corrosion performance," Imran explains. "With geothermal heat exchangers, there is a significant issue with scaling due to the temperatures and operating conditions. This leads to high maintenance costs, and similar issues."

On the project's website, Imran acknowledges the wider impact: "Heat exchangers in organic Rankine cycle (ORC) plants, including preheaters, evaporators, superheaters and condensers, account for a significant proportion of the plant total capital costs, and therefore reductions in cost related to these components will have a huge impact on plant profitability and could potentially mean that unviable low temperature geothermal resources become viable."

Horizon 2020

Horizon 2020 is the biggest EU Research and Innovation programme ever created with nearly €80 billion of funding made available over 7 years (2014 to 2020). With a focus on research, the programme is an investment in the future and therefore at the heart of the EU's blueprint for smart, sustainable and inclusive growth and jobs. It promises breakthroughs, discoveries and world-firsts by taking bold ideas from the lab to the market.
Source: https://ec.europa.eu/programmes/horizon2020/



A novel super hydrophobic coating developed by the TWI coating team using functionalised silica nanoparticles (Water contact angle of 150° on glass). Courtesy of TWI Ltd

Rigorous testing process

GeoHex plans to achieve reduced scale formation in geothermal heat exchangers by using a variety of different coating types, including hydrophobic coatings. The project aims to take development from lab-scale to full equipment scale; from working on small coupons, to heat exchanger test rigs, to relatively small but still representative heat exchangers, composing of proper geometry, corrugated plates, and pipes. Heat exchanger test rigs and representative heat exchangers will measure heat transfer and corrosion performance by passing fluids on both sides to test the coatings.

"We are using electroless nickel-phosphorus plating for the anticorrosion performance as well as amorphous coatings," says Imran. "And then for the working fluid and heat transfer side, we're using various hydrophobic coatings and also other types of thermal spray coatings. So, we are testing a range of options and different configurations."

A GeoHex test rig at ON Power, Iceland.

Current status

The project is funded for three years and was due to be completed in October 2022. However, as progress has been heavily impacted by the Covid-19 pandemic, the GeoHex consortium will request an extension of 6-12 months.

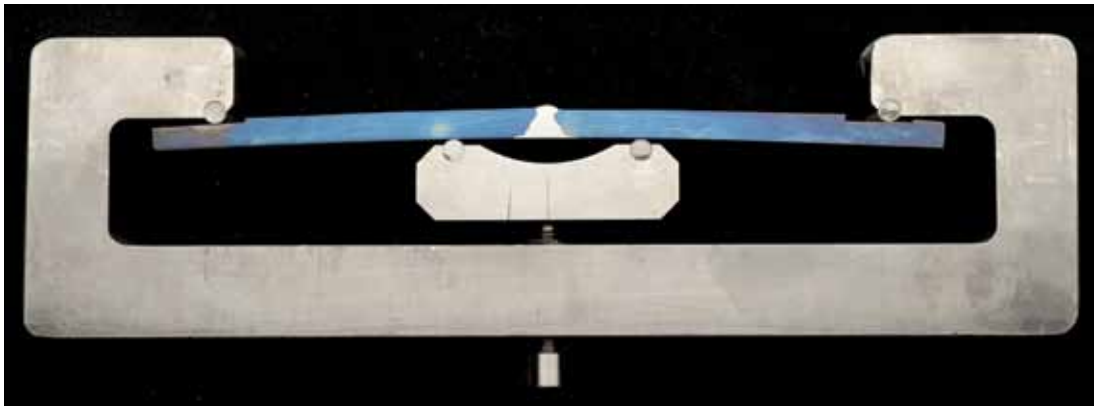
Despite these delays, Imran confirms that all of the coatings have now been developed. "We still need to carry out a lot of the small scale rig testing and, although we don't have any concrete heat transfer data, the preliminary results are positive."

The project intends to achieve all of its goals in 2023, but there are three major challenges to overcome before the project can be completed:

- Completing the rig testing which is currently in progress and hopes to be finished by the end of Q1 2022.
- Moving from small test plates to coating actual components – this means moving from flat test specimens to tubes, corrugated plates, and larger elements. The team hopes this aspect will be achieved by mid-2022.
- Implementing coatings in full sized heat exchangers – this is also planned by mid-2022.

Project lead and coordinator Namrata clarifies that the aim is to develop six prototypes of GeoHex materials in order to demonstrate the scalability and manufacturability. "However, another aspect of the project is a software tool, known as the 'knowledge based engineering' (KBE) tool and it has been combined with the decision support system," Namrata explains. "Whatever technical data is integrated as part of the various technical packages will be incorporated into the database. The idea is to feed in the information and get the output."

The project will also carry out life cycle analysis (LCA) to produce a cost model for the GeoHex materials to



Stress corrosion cracking testing. Courtesy of TWI Ltd

identify the environmental and cost performance – this again will become available as the project progresses. The technology developed by the GeoHex project will not only benefit geothermal applications but also any waste-heat-to-electricity application, such as steel-making. Imran believes that the efficiency of these systems is at the best they can be at the moment and that GeoHex will facilitate an even more efficient process for the near future. This will be of great interest to those industries racing toward their Paris Agreement climate goals as we approach 2030.

How a binary geothermal power plant works

The GeoHex project is working specifically to solve heat transfer and corrosion issues in binary geothermal power plants, which use a binary cycle to generate electricity from low temperature sources. Binary plants use a low boiling point refrigerant instead of water or steam. Hot water (geothermal separator water or geothermal brine) is passed on one side which boils off the refrigerant on the other side, the refrigerant then travels around to the turbine and creates electricity before coming back through a condenser and the cycle repeats.

The refrigerant is the same fluid used in air conditioning applications and is relatively benign from a materials perspective. The brine on the other side is what causes the scaling and corrosion issues as it contains a high level of silicates and the high temperature can encourage those silicates to come out, which results in silica scaling. Often, this scaling must be 'blasted' away, leading to down time and related cost. It is here where the GeoHex coatings will come in to play.

Group effort

Whilst the role of TWI is project coordination and management, ensuring that GeoHex's goal is met in the funded timescale, the project is backed by a strong team of 13 partners each providing support, knowledge, and specialist expertise. Namrata explains each enterprise's role in the project.

"In Iceland, we have power plant operators named, ON, who will provide site data and support testing in geothermal brine, as well as Grein Research who have worked on the coatings development. ICETEC is another company involved in the testing aspect of the project, as well as participation from University of Iceland."

"We have the end-users Quantum Leap in the Philippines who will provide data and best practices as the country's government has mandated that more geothermal plants are built as an energy source in the next ten years," Namrata continues. "Our partner in Norway, FlowPhys AS, has expertise in the development of FEA for fluid-structure interaction and turbulent flows analysed by large eddy simulation(LES), and have used their knowledge to perform shape optimisation."

"The Polytechnic University of Bucharest has developed multi-walled carbon nanotube (MWCNT) coatings by chemical vapour deposition. A small engineering company in Italy named Spike Renewables developed the testing rigs. In France, CEA built the heat exchanger prototypes and ENOGIA is another company building test rigs for the project."

The UK, representation comes from University of Leicester which has developed various coatings, and Technovative Solutions which will develop GeoHex knowledge based engineering (KBE), decision support system (DSS) and perform sustainability analyses. They will investigate opportunities around GeoHex and impact analysis.

The GeoHex Consortium.

GeoHex global consortium

Iceland – ON; University of Iceland; ICETEC; Grein Research
Norway – Flowphys AS
UK – TWI Ltd; Technovative Solutions; University of Leicester
France – CEA; ENOGIA
Italy – Spike Renewables
Romania – Polytechnic University of Bucharest
Philippines – Quantum Leap