Title: Strategies for the design and predictive maintenance of heat exchangers used in geothermal applications

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Problem statement

In the context of Europa's energy and climate targets, a strong drive exists towards the use of renewable energy. Geothermal energy, being the thermal energy generated and stored in the Earth, is an interesting resource. The heat can be used in heating networks or electricity can be generated by an Organic Rankine cycle (ORC). The composition of the pumped geothermal water can vary a lot depending on the drilled earth layer. In the campina of Limburg and Antwerp, for instance, the carboniferous limestone layer contains 3 to 4 times more salt compared to sea water. Moreover, the brine temperature is also relatively high (up to 150°C). Hence, the geothermal water is very corrosive to conventional materials which are used for heat exchangers and piping. Special materials, such as titanium, need to be used. Due to the high salt content and the high temperature, materials like titanium with quality grade 7 is required. This gives problems regarding machinability and weldability and the heat exchanger investment cost significantly increases. Compared to a stainless steel heat exchanger (Cr/Ni), the investment cost is about 8 times higher.

An alternative approach is to develop heat exchangers with a modular design, with components which resist corrosive media during a certain period (e.g. 3 years). After this period, the components are replaced by new ones. This approach raises some requirements on the design and the operation of the heat exchanger. The heat exchanger needs to be designed in a way which allows easy replacement of corrosion affected components. The material selection, coating and design should guarantee the minimal lifetime of the components in contact with the corrosive brine. Temperatures and temperature gradients have to stay within certain limits to avoid thermal stresses and stress.
Further, the selected material should have a limited impact on the required heat transfer surface area and the heat transfer rate.
The performance of heat exchangers is commonly monitored by temperature, pressure and mass flow rate measurements. Inlet and outlet measurements allow evaluating the heat exchanger's thermohydraulic performance. Deterioration of the performance can be an indication of corrosion or fouling. However, to evolve from preventive maintenance after a certain number of operation hours towards predictive maintenance based on measurements, local measurements in the heat exchanger are required. A local pressure drop measurement or temperature measurements might be useful. Also capacitive measurements may be an interesting technique

Objectives of the research

Heat exchangers are crucial components in geothermal projects: they should have an excellent thermo-hydraulic performance, they should resist aggressive media and at the same time their investment and maintenance cost should be such that the total cost of ownership (TCO) of the geothermal project remains economically feasible. The heat exchanger's performance, material selection and costs are conflicting issues which require an intelligent trade-off. The following research questions are apparent:

- Which heat exchanger type is most suitable?
- How strong is the corrosion of the brine towards materials? Which are the influencing parameters?
- Which influence do the investment and maintenance costs have on the TCO?
- Which intelligent design, material choice and maintenance strategy will lower the TCO?
- How to do a multi-objective optimization to obtain a high performant and cost-effective heat exchanger?
- Which measurements should be performed to allow predictive maintenance of the heat exchanger?

To answer these questions, three main objectives are distinguished in this PhD research project:

- Development of a design methodology for heat exchangers which takes into account the thermal hydraulic performance, the maintenance and investment cost and the lifetime of the heat exchanger.
- Development of monitoring techniques which allow evaluating the performance and lifespan of the heat exchanger.
- Development of a predictive maintenance strategy which indicates when maintenance or replacement of certain heat exchanger components is required based on measurements.
- Demonstration of the obtained result using a prototype?