Raising the Lifetime of Functional Materials for Concentrated Solar Power Technology

Edition: June 2018

Dear Reader,

In order to optimize the materials for molten salt plants and to establish the criteria for their selection, a precise knowledge of the corrosion rate and the failure mechanism of the employed alloys or coated steels at high temperature is necessary. In this third edition of the RAISELIFE newsletter we would like to introduce the work being doing in RAISELIFE to tackle this challenge, within the *Special Topic "Corrosion resistant high-temperature metals and coatings for molten salts"*. In addition, we share specific news from our consortium members.

We address this newsletter to stakeholders who are active in the field of Concentrated Solar Power Plants, from power plant developers / operators and technology suppliers to the scientific community as well as governmental bodies. Members from the general public who are interested in topics related to the RAISELIFE project, such as concentrated solar power and material durability will also gain from our newsletter.

We wish you an inspiring read!

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Special topic: Corrosion resistant high-temperature metals and coatings for molten salts

Partners involved

Universidad Complutense Madrid (UCM), Spain
Instituto Nacional de Técnica Aeroespacial (INTA), Spain
DECHEMA-Forschungsinstitut (DFI), Germany
Fraunhofer, Germany
BrightSource Industries (Israel) Ltd. (BSII), Israel

Importance of topic

The use of molten salts as heat transfer fluid (HTF) in solar power plants has the advantage of achieving higher operating temperatures (hence increasing the overall plant efficiency) at lower internal pipe pressures (minimizing the mechanical stress on the pipes). Additionally, this HTF can be used as heat storage medium, which saves heat exchangers. Typical requirements for the employed steels include resistance against elevated temperatures, temperature variations between day and night-time service, corrosive attack -especially by chloride and sulphate contaminants of salt mixtures-, and mechanical or erosive wear imposed by fluid movement.

Current state of art

The current state-of-the-art of CSP systems assumes a molten-salt power tower employing a 60/40 wt% mixture of sodium and potassium nitrate (known as Solar Salt) at a temperature of about 565°C. The current central tower CSP plants commonly use Cr-Mo stainless steels with Cr content up to 9%, Cr or Cr-Ni stainless steels with alloying elements such as Mo, Nb, Ti, and Ni- base alloys such INCONEL or HASTELOY type as base materials. High-chromium Ni-base alloys and high-chromium austenitic steels show lower corrosion rates in molten salt compared to the low-chromium steels. However, the cost of Ni-base alloys and high-chromium austenitic steels is huge. Since low-chromium steels possess the required strength, a low-cost solution could be to develop coatings to enhance their corrosion resistance.

The RAISELIFE approach

In RAISELIFE, the corrosion of in-service steel samples from commercial molten salt power plants is analysed. Laboratory corrosion tests are being performed on the materials currently used by BSII (Inconel-617 and T91), on promising material candidates for future projects (VM12-SHC steel tube materials manufactured by Vallourec, and nickel base alloy Haynes 230) and on low-alloyed material samples with protective coatings (multi metallic diffusion and aluminide coatings, developed by DFI and INTA respectively).

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The corrosion rate of the materials is being tested under static, cyclic and dynamic conditions by UCM in contact with different salts:

- the reference binary system (60 wt.% $NaNO_3$ + 40 wt. % KNO_3)
- cost-optimized $NaNO_3$ / KNO_3 binary systems with a modified weight distribution

The conducted tests are also focused on determining the impact of commonly present salt impurities such as chlorides and sulphates, which affect the chemical and thermal stability of the salt and the corrosive effect on materials. In addition, Fraunhofer is performing slow strain rate tests (SSRT) and thermo-mechanical fatigue tests. A detailed analysis and understanding of the failure mechanism of coated steel samples has been performed after 1000 h of testing in order to give feedback to coating developers for improved corrosion protection in molten salts. Long-term tests are currently on going in order to test the coatings which in the first stage of testing showed a better behaviour. Based on the whole study, a best practice for material selection for molten salt plants will be elaborated, also including the maximum admissible level of molten salt impurities to be compatible with the O&M of the plant.

In addition, electrochemical sensors for on-line corrosion monitoring have been developed by UCM to monitor corrosion rates in commercial power plants. The sensors have successfully worked in lab conditions and tests are planned with probes of different steels and coated substrates in a molten salt plant of BSII to continuously measure the corrosion rates of steel in contact with molten salt.

Possible impact

Next-generation CSP plants require high-temperature molten salts to store heat for electricity generation. However, molten salts wear away common alloys used in CSP systems. Thus, results achieved will directly impact on CSP plants through the mitigation of corrosion levels, which will reduce the Levelized Cost of Energy of this technology.

News

The challenges for tubular solutions are defined

Using molten salt as heat transfer fluid is a challenge for engineers and for companies delivering components for Solar Power Plants. This also applies to tubes and pipes. During the RAISELIFE project, Vallourec discussed with several solar players about the specific demand of the tubular solutions for solar power plants. Meanwhile the needs and requirements are outlined. The technical sticking points are identified and the next

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step is working on intelligent tubular solutions to meet all the requirements. Based on its long-standing experience in the steels and alloys already used in the energy market, Vallourec shares its expertise in the most advanced ferritic steel, stainless steel or nickel base alloy tubes and can also develop new tailor-made solutions for the specific demand of tubes submitted to particularly corrosive environments such as molten salts currently envisaged in solar power plants.

Especially Vallourec's experiences made in nuclear power plants seem to be very helpful for tubular solutions for solar power plants and the experts see opportunities to draw parallels. First ideas have to be underpinned either by testing material already used in nuclear power plants with molten salt or by finding other proper ways to provide the most competitive tube in the requested size range.

The challenge is defined. The future will show whether to find the right solutions with the well-known T22, T91 or VM12-SHC steel grades or with the nickel base such as IN617 whose properties allow meeting higher temperatures and more corrosive environment.

Author: Vallourec, Carine Landier

Improved durability for Secondary Mirrors using an Plasma Enhanced Chemical Vapour Deposition top coating

Secondary mirrors allow a potentially smaller absorber area, resulting in not only a reduction in thermal losses but also reduced costs by eliminating the need for the expensive refractory material shield around the absorber.

In order to reach the required high reflectance for the secondary mirrors, sputtered thin film silver is used. Thin film silver, however, agglomerates. This process is accelerated by temperature and also by humidity. The silver must be embedded in a stack of adhesion and barriers layers which suppresses the agglomeration yet minimally diminishes the high reflectance.

Within the Raiselife project, the team at the Fraunhofer ISE trialled a broad range of barrier layers and adhesion layer stacks. Highly promising was the use of a PECVD (Plasma Enhanced Chemical Vapour Deposition) coating. An optimal thickness and porosity was found, which allowed protection of the mirror not only at temperatures of 400 °C (the operating temperature of the secondary) but also in cooler, humid conditions (representative of an accelerated aging system of conditions at night).

Author: Sophie Gledhill, Fraunhofer ISE

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MinWaterCSP Conference Marrakech, Partner Project

The consortium of the H2020 funded project MinWaterCSP organized the first International Conference, which took place in Marrakech, Morocco from 24th to 25th April 2018.

The topic of this event was Reduction of water consumption in Concentrated Solar Power (CSP) plants with a special focus on new approaches in mirror cleaning, cooling system solutions and overall plant performance simulations. The aim of the conference was the presentation and discussion of new technological solutions to minimize water consumption in CSP plants as well as to create networking opportunities. The two-day conference gave valuable insights into innovative solutions for mirror cleaning and anti-soiling, cooling systems, axial flow fan development, simulation-based analysis of CSP plant water consumption and water management strategies. Anna Heimsath, from Fraunhofer ISE, was invited to give a talk on mirror degradation and soiling, during which she had the opportunity to show the results of the RAISELIFE project.

The event was targeted at stakeholders from Power utilities, Power plant operators, Technology suppliers, Research institutes and Academia that are working in the fields of concentrated solar power. Further stakeholders for mirror cleaning, cooling processes or similar, any users of those technologies, policy makers and investors interested in the topics where also invited to participate.

Author: Anna Heimsath, Fraunhofer ISE

Link to news: https://www.minwatercsp.eu

Meet us at Events

EFC-Workshop 2018: High Temperature Corrosion under Complex Conditions, Deposits and Salts: Towards Greener Energy, 26 - 28 September 2018, represented by INTA
http://dechema.de/efcws2018.html

SolarPACES 2018 in Casablanca (Morocco), 02 – 05 October 2018, represented by DLR, CIEMAT, DFI, Fraunhofer
www.solarpaces-conference.org

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