Materials and Systems for Liquid Metal based CSP 2.0

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1. Introduction

Concentrating solar power (CSP) based on liquid metals as heat transfer fluid (HTF) offers a technically attractive option for compact efficiently operating power stations, which can flexibly provide heat and/or power to different grids at a simultaneous small resource footprint. Based on long experiences in research and development, the utilization of liquid metals not only reduce investment and operational costs due to the excellent properties for heat transfer and storage [1] but also allow for long service life times and environmentally low recycling costs. Safety concerns often expressed, in particular for sodium-operated installations can be mastered by efficient design, operation provisions [2] and innovative material solutions [3]. However, more flexible operation of future power plants located in grids of time-varying feed-in sources require larger temperature ranges, which formulate new demands on structural and functional materials, such as fatigue or failure tolerances, in order to avoid cost-intensive damages or even plant outages. On the other hand, higher temperatures enhances plant flexibility on a wider range for process heat applications. Here, the paper focus on recent developments in testing of equipment and materials for liquid sodium up to 750°C.

2. Recent technological advancements

As part of the material development task of the Helmholtz Energy Materials Characterization Programme (HEMCP), dedicated facilities have been developed and set into operation at KIT as shown in Fig 1. Being part of the LIMCKA project, (LIquid Metal Competence center KArlsruhe) [7] they cover all aspects of the liquid metal technology from room temperature (for education and training purposes) up to app. 1000°C for Alkali Metal Thermal Electric Conversion (AMTEC) tests [4, 5]. The KARIFA facility will allow qualifying receiver materials under fast thermal transients using IR-Laser flash irradiation on different areas.

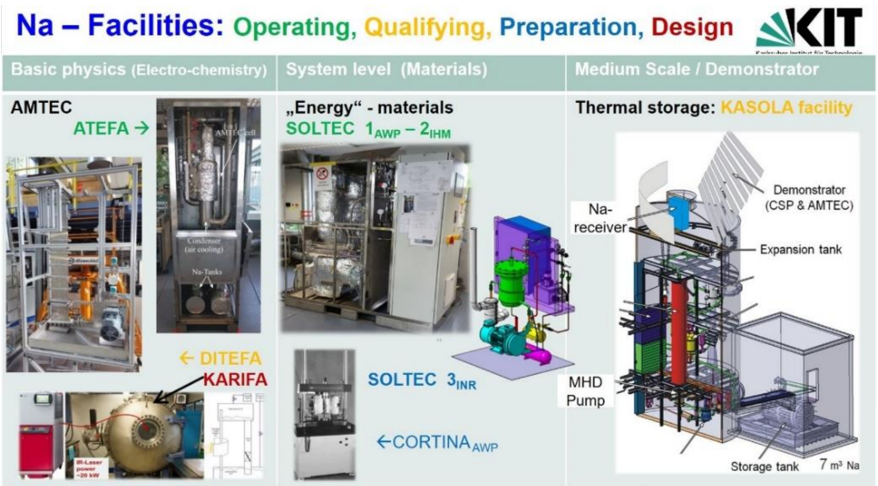

Fig. 1 Summary of liquid metal facilities within LIMCKA used for material qualification and component testing from room temperature (DITEFA) up to 1000 °C (ATEFA, KARIFA).

The material research focus is currently directed not only to structure materials but also towards high heat flux solutions. One of them are tungsten-laminates being of high relevance for CSP to remove efficiently heat, which demonstrated successfully in the High Heat Flux (HHF) facility at the Plataforma Solar de Almería, Spain, and at the Max Planck Institute of Plasma Physics (IPP), Garching, Germany [3] an exceptional performance. Next steps are low and high cycle fatigue as well as materials subjected to fast thermal transients with locally varying heating input (spot, surface, volumetric) inducing material stress.

3. Required next steps

Having all these components qualified, the next step is the demonstration of the system functionality by a demonstrator, to study and analyze the interplay of receivers, plus an optional topping system empowered by AMTEC (Alkali Metal Thermal Energy Convertor) [5] with an innovative thermal storage concept. Two concepts were developed: (1) transfer one of the mobile SOLTEC (Sodium loop to test Materials and Corrosion) facilities to a solar furnace or (2) extend the existing KASOLA facility with a small mirror system on the roof as shown in Fig 2. The design uses dedicated mirrors fabricated by FRENELL and standard trough to increase concentration necessary to achieve the high heat flux.

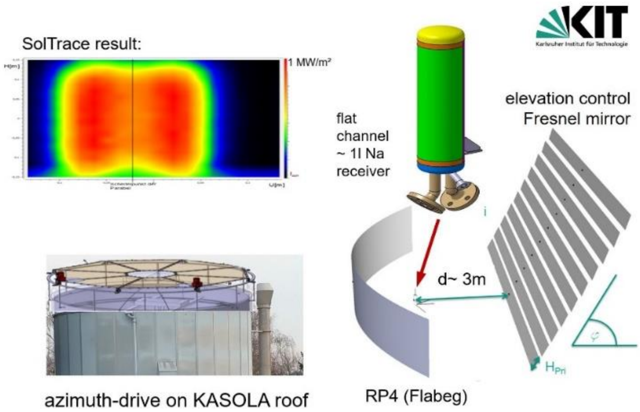

Fig. 2 Concept of a sodium receiver test assembly, combining FRENELL mirror – trough concept to achieve high concentration rates and thus heat densities up to 4 MW/m².

4. Summary

The clear definition of the step to bring a complete technology from the labs to industry is shown focused on an inherent demonstrator integrated into the KASOLA tower. The concept allows, even under the non-ideal solar conditions in the Rhine valley high power loads assuming a radiation density of 700W/m². Here, the demonstrator will comprise in the first phase a simple sodium receiver, which is replaced in the second phase by a receiver optimized for AMTEC.

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