SOLAR THERMAL COLLECTORS AND THEIR COMPONENTS. RESULTS OF LONG-TERM EXPOSURE AT EXTREME TEST SITE

Summary

The reliability of solar thermal collectors is of great economic importance for suppliers, manufacturers and operators due to the long lifetimes demanded by the market. However, it is naturally strongly influenced by the specific climatic conditions at the installation site and is therefore difficult for the industry to estimate. The determination of the load factors for collectors and components under the conditions of the various extreme outdoor weathering locations offers the possibility of influencing the design of thermal solar collectors and components.

To quantify the ageing behavior of solar thermal collectors and their components, we exposed solar thermal flat plate collectors to locations in moderate as reference and with harsh conditions in tropical, alpine, arid and maritime climates. The performance of the solar thermal collectors was measured before and after the outdoor exposure. In order to quantify the influence of the soiling of the transparent cover, the collectors were measured without cleaning and after cleaning. After the performance test, the collectors were opened and subjected to a visual inspection. The effect of direct deposits on the absorber plate and the transparent cover were quantified using spectroscopic measurements.

In this paper we present the results of the latest collector measurements. An exposure time of ten years under stagnation conditions was achieved. This exposure time corresponds to approx. 50 - 100 years of real operation, depending on the location and the application.

Keywords: Solar thermal collectors, components, durability, degradation, optical characterization, thermal stress

1. Introduction

In the SpeedColl and SpeedColl2 [1] projects, a consortium consisting of Fraunhofer ISE and the University of Stuttgart has been working with industry representatives on the loads and resulting tests for solar thermal collectors and their components. As part of the joint project, solar thermal collectors and components were exposed to various climatic regions. The exposure locations were equipped with comprehensive load monitoring to continuously record environmental conditions relevant to ageing. The aim of the exposure was to uncover any weak points at an early stage and to improve the reliability of solar thermal systems in the long term. Ageing effects of components in flat-plate collectors are mainly determined by the temperature level and humidity in the collector. Recently, the trend towards systems with higher solar fractions has led to an increase in stagnation times and temperatures.

The locations are characterized by typical combinations of different stress factors, such as high UV radiation with mechanical wind and snow loads at the Zugspitze location, or strong irradiation at high temperatures and day-night differences at the desert location in Israel. At the maritime location on Gran Canaria, wind loads usually occur in addition to high humidity with a high content of salt aerosols [2].

For the investigation of the weather resistance of solar thermal materials and the analysis of macro- and microclimatic degradation factors, findings from outdoor weathering are indispensable. At the outdoor weathering sites of the SpeedColl 2 project, meteorological data was measured every minute in addition to collector-specific parameters such as absorber or adhesive joint temperatures. Load profiles were created from the recorded data. From the stress profiles, conclusions could be drawn about the effects of the combined stress factors such as UV radiation, humidity, temperature and corrosiveness on the test specimens, which were used for the development of adequate rapid tests.

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2. Results

Three different solar thermal collectors types we exposed in various extreme climates while continuously monitoring the outdoor climatic conditions and the micro-climate inside the collector. Within the project, a complex quality assurance of the measured data was successfully defined and implemented. The highest absorber temperatures, up to 225 °C, were measured at the alpine exposure site [3]. The performance of the solar thermal collectors was measured in accordance with the test standard ISO 9806:2013 [4].

In Figure 1 exemplary the comparative performance curves for one solar thermal collector as reference before exposition and after 2.5 years, 7,5 years and 10,0. years of dry exposition (stagnation mode) and the relative deviation to reference at maritime exposition site Gran Canaria are shown. This Figure shows the collector efficiency after cleaning the transparent cover, where G is Global irradiance, $T_{fl,m}$ is the fluid mean temperature and T_{amb} the ambient temperature. The measured difference in collector efficiency before and after cleaning the transparent cover for the collector after 10.0 years of exposure was 17%.

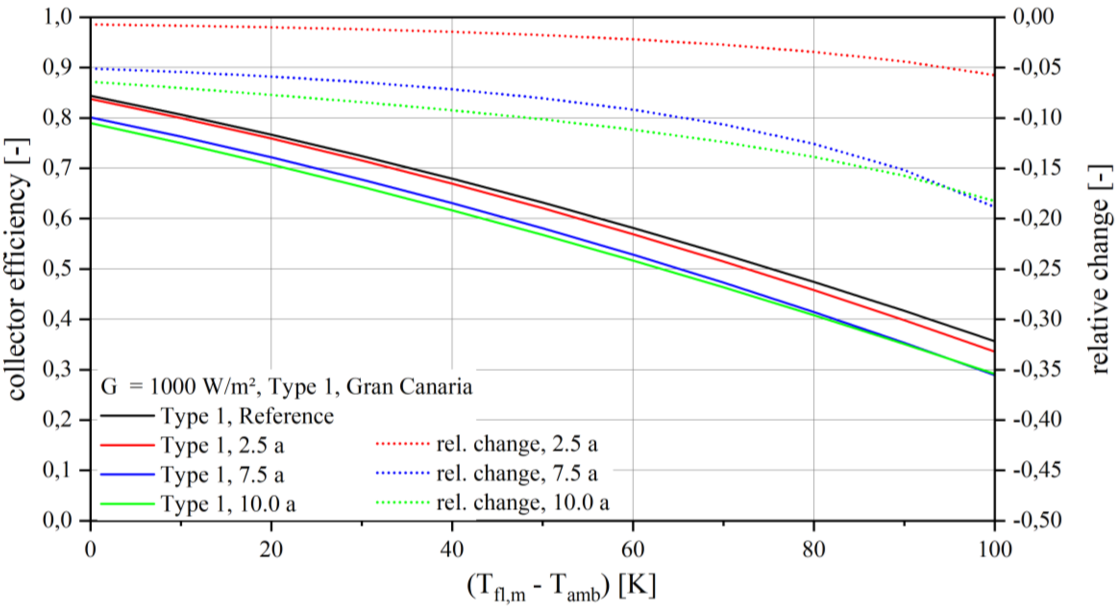

Figure 1 comparative performance test according to ISO 9806:2013 for reference before exposition and after 2.5 years and 7.5 years and 10.0 years of dry exposition and relative deviation to reference at maritime exposition site Gran Canaria

After the performance measurements, the collectors were opened and a visual inspection was carried out. Observed degradation effects were:

- soiling of the glass cover
- fogging on the inside of the glass cover
- partial weld seam detachment on absorber (figure 2)
- deformation of absorber with contact to glass cover
- corrosion on the collector frame, bottom plate and absorber
- increase in thermal conductivity of thermal insulation.

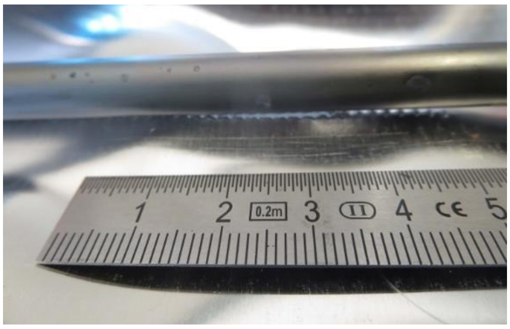

Figure 2 Absorber plate approx. 40 mm cracking on laser weld seam of the heat transfer pipe frontside (left) and backside (right) after 8.3 years of dry exposition at maritime exposition site Gran Canaria

The solar absorber was characterized as described in the standard testing in ISO 22975 [5].

In figure 3 three prepared pieces of the solar absorber not cleaned and cleaned after 7 years exposure mounted inside a solar thermal collector in stagnation mode are shown. Exemplary the collectors were of type 3 exposed at the alpine (Zugspitze, Germany), the maritime (Gran Canaria, Spain) and the arid climate (Negev, Israel). On the left side the picture of the prepared absorber are shown. On the right side the spectral reflectance measurements with the weighting functions normalized solar spectrum (AM 1.5) and normalized Planck spectrum (373 K) for emittance are shown.

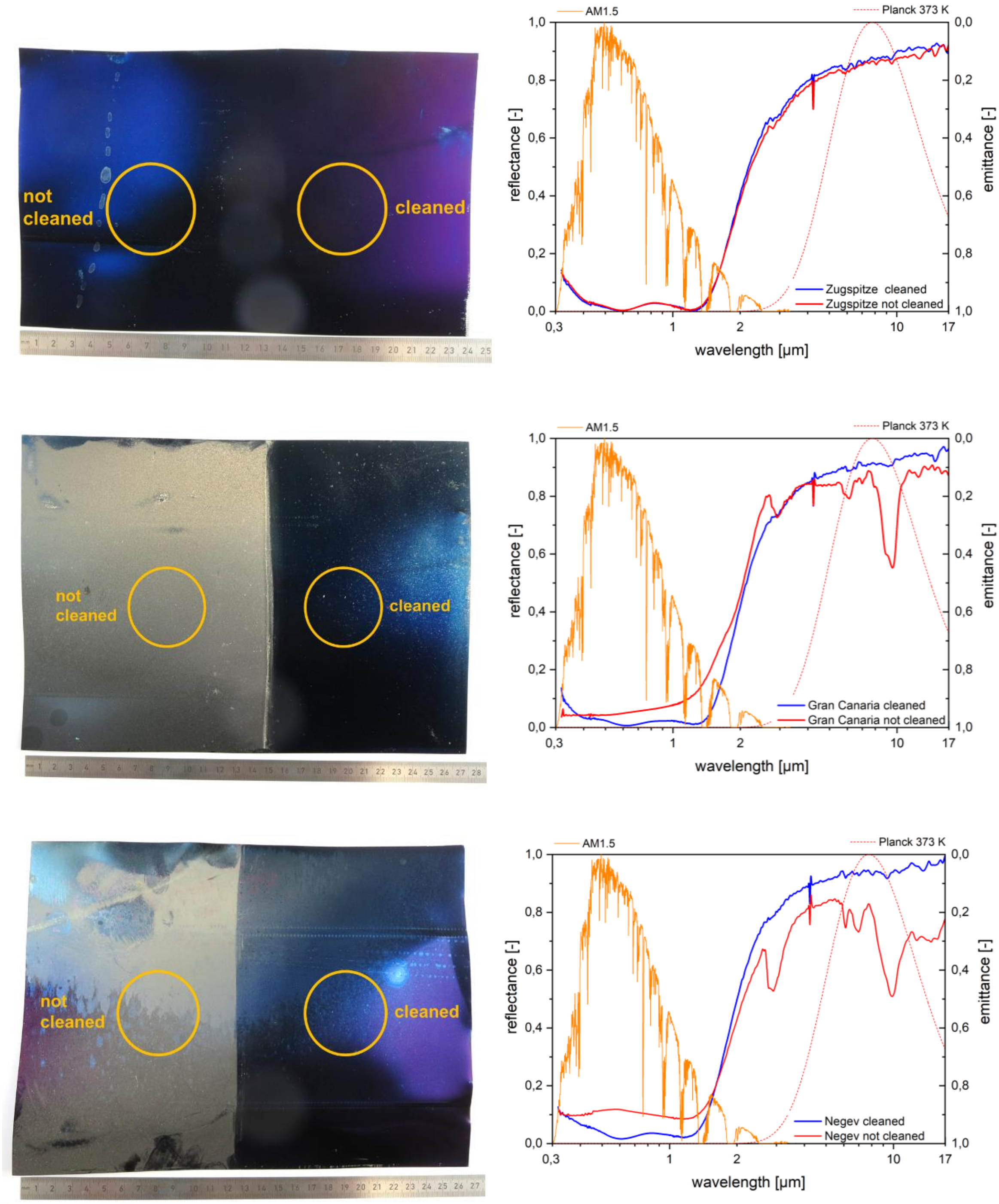

Figure 3 Left side the picture of the prepared absorber and measured reflectance of solar absorber not cleaned and cleaned after 7 years' exposure mounted inside a solar thermal collector in stagnation with weighting functions normalized AM 1.5 solar spectrum for reflectance and normalized Planck spectrum for 373 K for emittance.
Top: alpine (Zugspitze, Germany), middle: maritime (Gran Canaria, Spain), bottom arid climate (Negev, Israel)

In table 1 the values for the solar absorption (α [AM1.5]) with the weighting function of the solar spectrum AM 1.5 and the thermal emittance value (ε [373K]) with the weighting function of a Planck spectrum for 373 K for the not cleaned and cleaned spot are shown for the three different exposition sites alpine, maritime and arid. The differences (Δα,Δε) and the relative changes ($rel_{\Delta\alpha}$, $rel_{\Delta\varepsilon}$) are shown, too.

Type 3	α [AM1.5]		ε [373K]		Δ α	Δ ε	$rel_{\Delta\alpha}$	$rel_{\Delta\varepsilon}$
	not cleaned	cleand	not cleaned	cleand	$\alpha_{cleaned} - \alpha_{not\ cleaned}$	$\varepsilon_{cleaned} - \varepsilon_{not\ cleaned}$	$\Delta\alpha / \alpha_{cleaned}$	$\Delta\varepsilon / \varepsilon_{cleaned}$
Zugspitze	0,956	0,957	0,126	0,110	0,001	-0,016	0,001	-0,140
Gran Canaria	0,874	0,954	0,288	0,077	0,080	-0,211	0,084	-2,758
Negev	0,848	0,935	0,268	0,054	0,087	-0,214	0,093	-3,985

Table 1 solar absorption and the thermal emittance value for the not cleaned and cleaned spot, differences and relative changes at exposition sites alpine (Zugspitze), maritime (Gran Canaria) and arid (Negev)

The results show a very different behavior in terms of the optical change of the absorber and the exposition site. The relative change of solar absorption and the thermal emittance are very small at the alpine exposition compared with the changes at the maritime and arid exposition.

To determine the influence of the collector performance degradation in terms of energy savings in a solar thermal system in a normal operating mode, system simulations were carried out using the TRNSYS simulation program and the reference system for domestic hot water heating [6] and reference combined system [7] as defined in IEA SHC TASK 54. The simulations were carried out at the Institute for Building Energetics, Thermotechnology and Energy Storage, Univ. of. Stuttgart, Germany. The observed performance degradation is in the range of 2% to 16 % in the proportionate primary energy saving (reference combined system Würzburg 15 m² flat plate collector).

Overall, even under the extreme conditions of the outdoor weathering test, due to the extreme climatic loads and the permanent stagnation over the entire exposure time, the collectors under consideration and their components show only low degradation effects, which suggests a very long service life under normal operating conditions.

3. Acknowledgements

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4. References

[1] Development of Accelerated Aging Tests for Solar Thermal Collectors and their Components www.speedcoll2.de

[2] Slamova, K., Duerr, I., Kaltenbach, T., Köhl, M., 2016. Degradation effects of maritime atmosphere on metallic components of solar collectors. Solar Energy Materials & Solar Cells 147, 246–254

[3] Kaltenbach, T., Heck, M., Kaaya, I., Standard testing of absorber surface durability according to ISO 22975–3 versus measured thermal and high-humidity stress of absorber surface at extreme test sites, Solar Energy Advances, Volume 3, 2023, 100042, ISSN 2667-1131

[4] ISO 9806:2013, Solar energy — Solar thermal collectors — Test methods

[5] ISO 22975 Part 3:2013, Solar Energy-Collector components and materials, Absorber surface durability

[6] Bachmann, S., Fischer, S. et al. (2018) Info Sheet A08: Reference System, Germany Solar Domestic Hot Water System for Single-Family House http://task54.iea-shc.org/Data/Sites/1/publications/A08-Info-Sheet--Ref-SF-SDHW-System--Germany.pdf

[7] Bachmann, S., Fischer, S. et al. (2018) Info Sheet A08: Reference System, Germany Solar Domestic Hot Water System for Single-Family House, A09-Info-Sheet--Ref-SF-Solar-Combisystem --Germany.pdf