Polymer Collectors with Temperature Control Thermosyphon Valve Development and System Integration

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Abstract

The goal of several projects in Europe is to develop and design collectors made out of polymers. A main boundary condition for such polymer collectors is the possibility to use as cheap as possible polymer material, which can typically withstand temperatures only up to about 95°C. Therefore solutions for limiting the temperatures during stagnation are looked for. One possible solution is a collector with integrated thermosiphon cooling, which limits the temperature during stagnation, but also allows the design of a collector with highest possible efficiency during operation. Based on this collector type also solar domestic hot water systems (SDHW) and solar combisystems (SCS) as well can be developed and operated under different boundary conditions in a new way. In a single family house a solar combisystem with overheat controlled polymer collector in combination with building mass activation can achieve a solar fraction which is comparable with conventional high performing flat plate collector systems coupled only to a water storage. In solar domestic hot water systems a polymer collector system with thermosiphon cooling can avoid stagnation periods, which allows restarting at any time also after a high insulation period during noon. This gives the potential to reduce the disadvantage of reduced efficiency during operation by longer operation periods in comparison to standard flat plat collectors.

Keywords: Solar Thermal, Solar Collector, Polymer Collector, Simulations

1. Introduction

Within the Austrian research project SolPol-4/5 it is the goal to find solutions for solar thermal systems based on cheap polymer materials but with low temperature limits in order to realize significant cost reduction potentials. Therefore one major point is to keep the temperature of the solar collector (and the complete system) below the material limits which means below 100°C for cheap polymer materials. For this, several possibilities are under investigation in many research projects. One solution is to design the collector in such a way, that the performance does not allow stagnation temperatures above 100°C (temperature limited collector – TLC). Other solutions try to keep the collector performance highest possible during operation and reduce the performance during stagnation by different technical solutions (overheat controlled – OHC) like reduction of absorption characteristic at high temperatures (Föste et.al., 2015), reduction of transmission of the transparent cover or increasing the heat losses by activating cooling processes like internal ventilation of the collector (Harrison et.al., 2004).

Within this project the concept using a thermosyphon driven backcooler (Thür, 2014; Thür and Maslikova, 2016) was further developed and improved.

The main idea is to design a best possible collector for operation and to integrate a thermosiphon cooling element for stagnation periods which is intrinsically save and keeps the temperature within acceptable limits. This concept enables highest possible collector efficiency and also the possibility to switch on and off the collector loop at any time without evaporation of the collector fluid. Fig. 1 shows the principle concept of the thermosiphon cooling concept. In fact it works like a solar thermal thermosiphon heating system, but instead of the hot water tank an additional absorber is mounted on the rear and operates as a cooler. Depending on the collector temperature and/or the operational status of the solar heating system a special valve activates or closes the connection to the backcooler. Otherwise the collector operates as an ordinary flat plate collector in a pumped solar heating system.

doi:10.18086/eurosun2018.01.08 Available at http://proceedings.ises.org

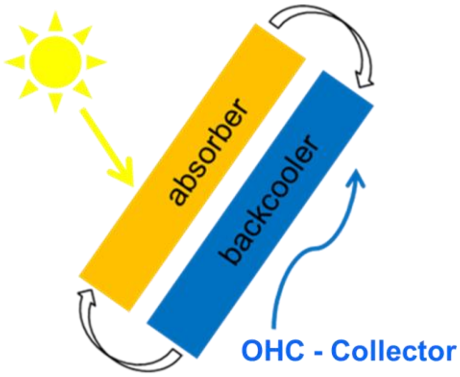

Fig. 1: Principle of a OHC-collector with a thermosyphon driven backcooler

Beside component testing simulation studies were performed with this advanced collector type for solar domestic hot water systems (SDHW) and solar combisystems (SCS) under Austrian climate conditions.

2. Collector development

Based on an existing polymer collector as a basis, a thermosiphon driven back cooler was added and the performance of the collector was increased in order to develop an overheat controlled (OHC) collector which has higher performance during operation but still keeps the limit of less than 100°C maximum material temperature during stagnation. A main part of this collector concept is a new developed valve which ensures a fail save switching between operation and stagnation of the collector. This collector was tested at the outdoor test facility of University of Innsbruck.

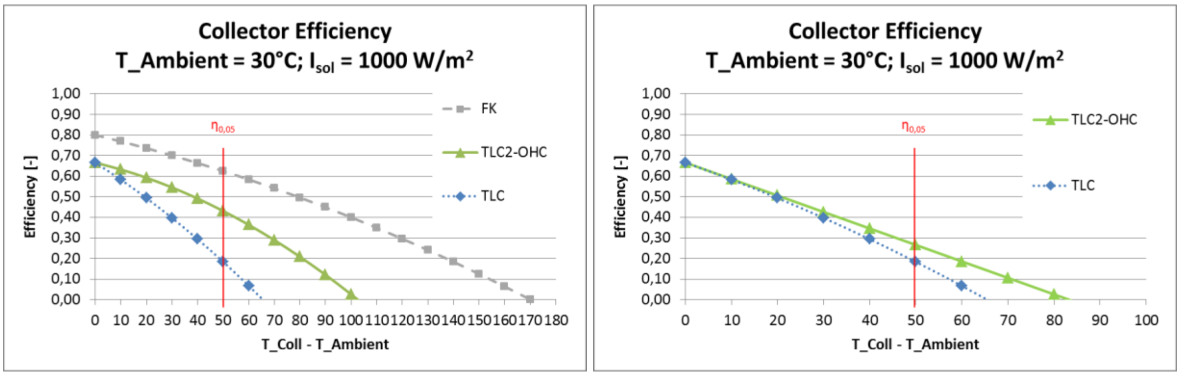

Fig. 2: LEFT: Theoretical Collector Efficiency Curve for TLC-Collector with 95°C Stagnation Temperature and TLC2-OHC Collector with 135°C Stagnation Temperature as theoretically calculated (but limited to 95°C due to backcooler) and a Standard Flat Plate Collector (FK) as Reference. RIGHT: Status of tested TLC2-OHC which does not completely reach the theoretical calculated efficiency of TLC2-OHC in left graph.

The difference in stagnation temperatures is demonstrated comparing Fig 3 (without back-cooling) and Fig 4 (with back-cooling). The maximum material temperatures due to back-cooling can be reduced from about 120°C (dotted red lines in Fig 3) to slightly less than 100°C (dotted red lines in Fig 4).

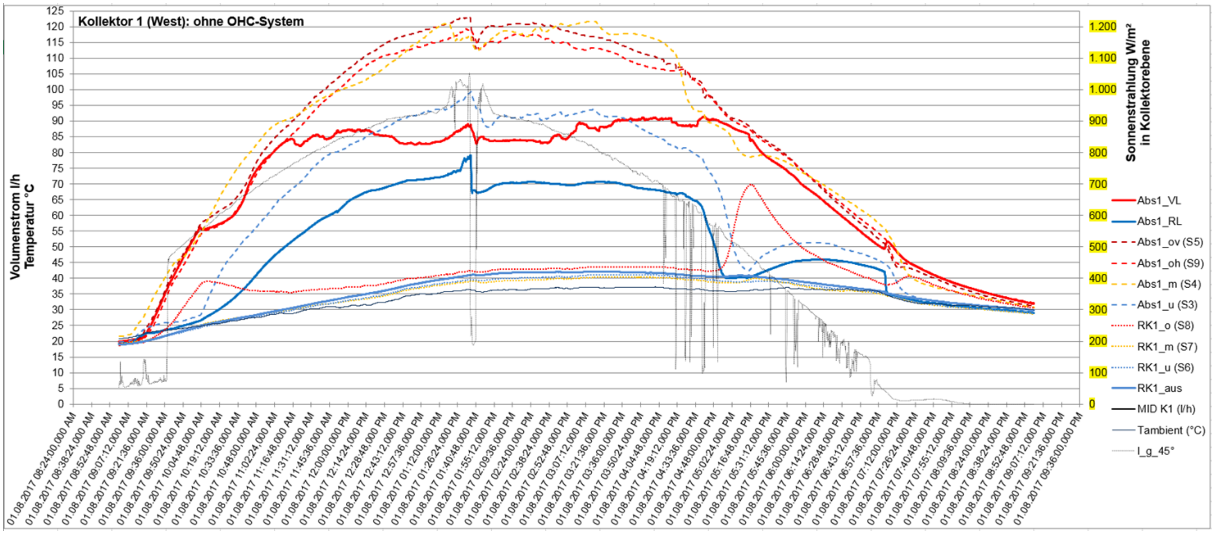

Fig. 3: Stagnation test without back-cooling (absorber inlet temperature "Abs1_RL" is around 70°C where back-cooler outlet temperature "RK1_aus" is close to "Tambient" which indicates that there is no thermosiphonal mass-flow; also all temperatures of the back-cooler "RK1_o,m,u" are around ambient temperatur "Tambient")

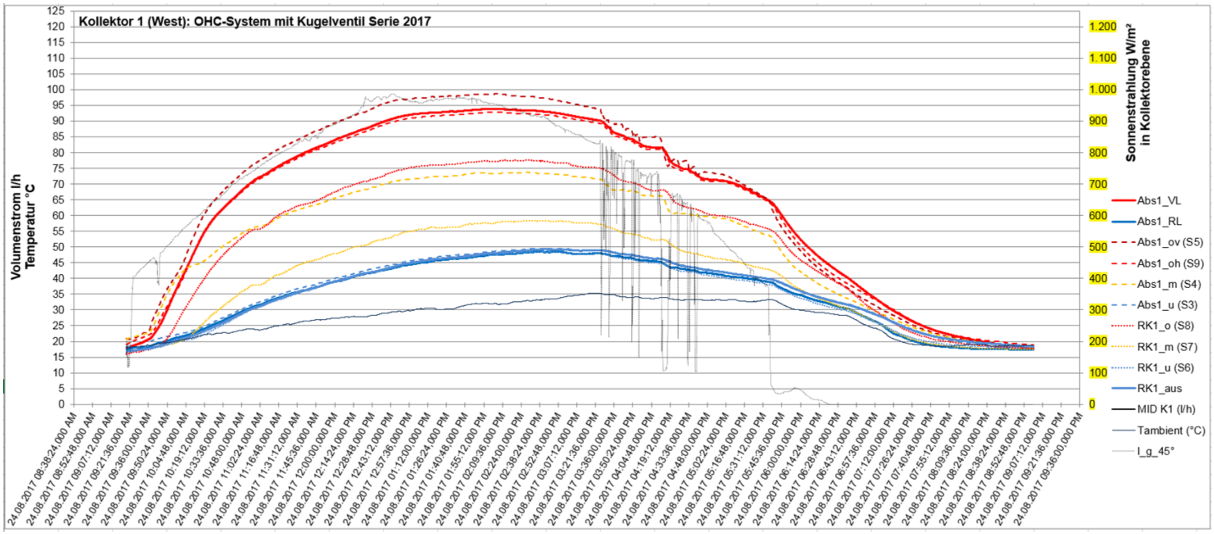

Fig. 4: Stagnation test with back-cooling (absorber inlet temperature "Abs1_RL" is around 50°C as maximum and identical to back-cooler outlet temperature "RK1_aus" which indicates that there is a thermosiphon mass-flow; also all temperatures of the back-cooler "RK1_o,m,u" show a clear gradient from top ("RK1_o" = 77°C) to middle ("RK1_m" = 57°C) and bottom ("RK1_u" = 50°C))

A more advanced back-cooler with about 3 times more volume and therefore lower velocity in the thermosiphon back-cooling flow showed potential to further reduction of stagnation temperatures by additional 8°C; maximum temperatures in Fig 4 therefore would reach about 90°C.

3. System simulation – Solar Domestic Hot Water (SDHW)

Fig. 5 shows the simulation results of a SDHW system located in Innsbruck (Austria) with a 295 Liter DHW-tank and hot water consumption of 200 Liter per day. The system with TLC2-OHC collector (6 m^2 collector area) can achieve around 25% higher solar fraction (SF=50%) compabred to the TLC collector (SF=40%).

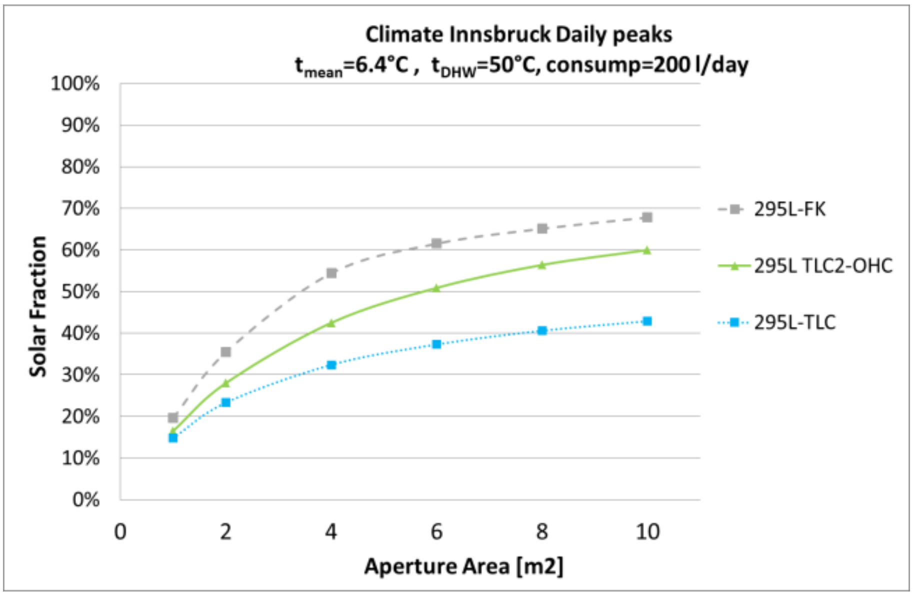

Fig. 5: Simulation results of a solar domestic hot water system with significant higher solar fraction of the system with TLC2-OHC compared to TLC collector.

4. System simulation – Solar combisystem (SCS)

For SCS systems a conventional flat plate collector with thermal energy storage (TES) was compared with TLC and TLC2-OHC collectors which also use the building mass via concrete core activation as heat storage (BUI+TES). The heat load of the investigated single family house is 6700 kWh for space heating and 2175 kWh for domestic hot water. Fig 6 shows the concept of possible solar thermal heat flows:

1. from solar thermal collector to thermal energy storage (TES) heating up to 60°C in winter and up to 90°C in summer.
2. from solar thermal collector direct to the building via the floor heating system using the building mass as thermal storage (BUI) by heating up to a room temperature of 23°C as a maximum.
3. as auxiliary a heat pump (HP) is heating the TES up to 50°C or directly the floor heating system to keep the room temperature at 21±0.5°C

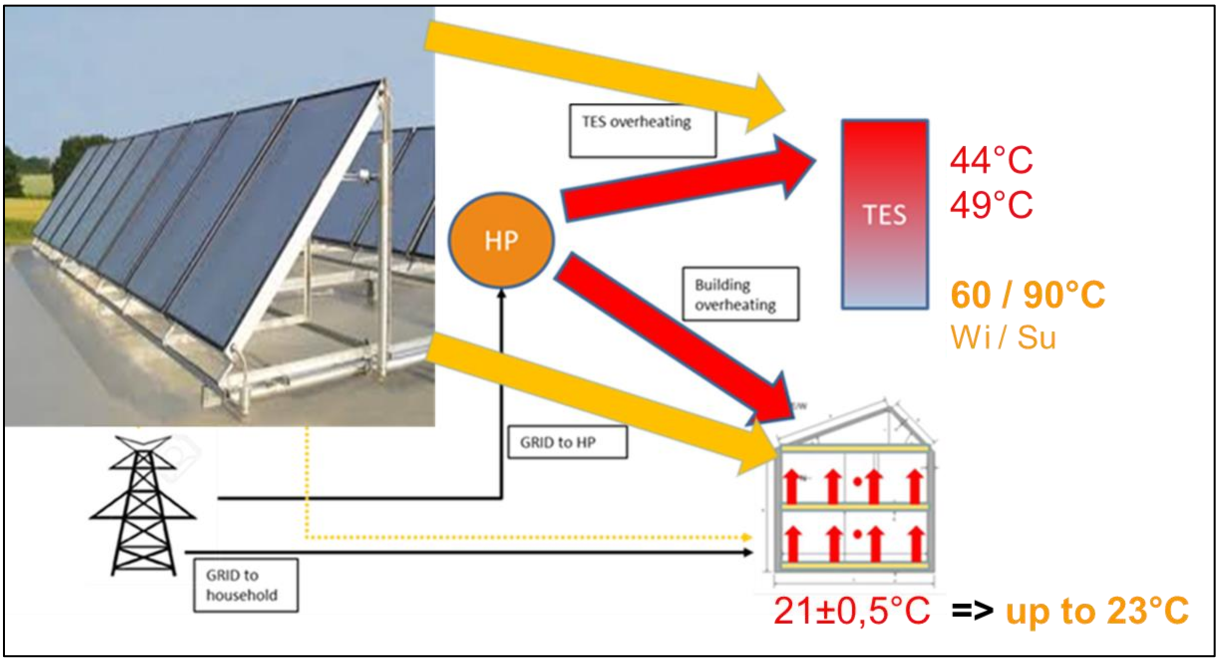

Fig. 6: Possible heat flows from solar thermal collector to TES and to the building directly.

As shown in Fig. 7 a solar combisystem (SCS) with TLC2-OHC combined with BUI+TES can achieve about the same solar fraction as a conventional system (FK with TES), where just the TLC shows a significant reduced solar fraction.

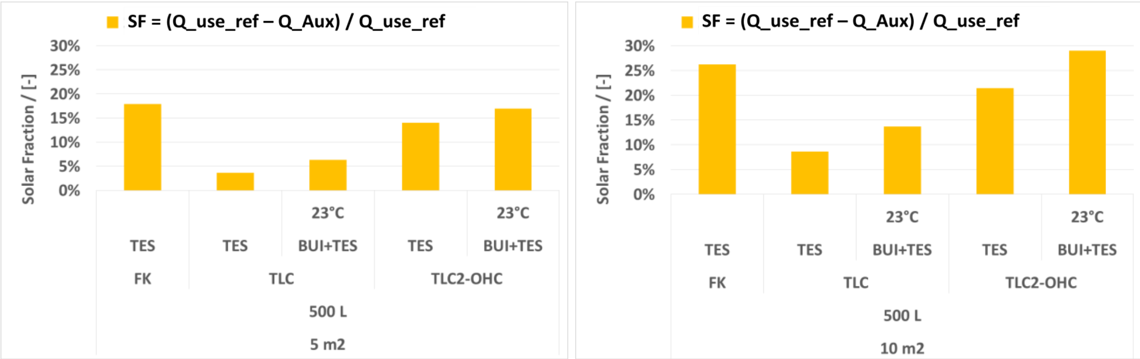

Fig. 7: Solar fraction of solar combisystems with 500 liter water storage combined with 5 and 10 m^2 collector area respectively.

As shown in Fig 8 the TLC2-OHC collector in combination with building mass activation also shows a high potential to achieve high solar fraction with increasing collector area but keeping the water storage very small. This gives to possibility to place the water storage inside the living area with minimized pipe length and useful heat loss during winter season.

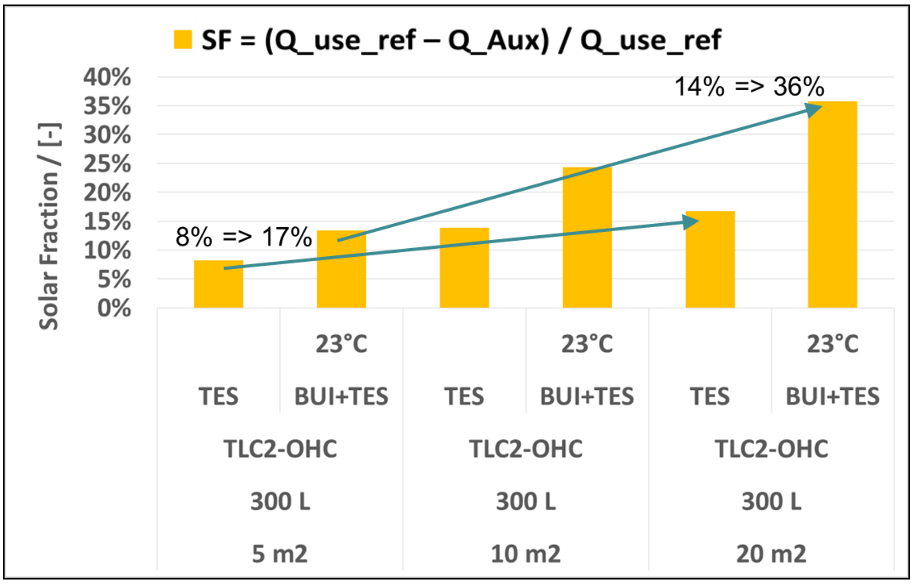

Fig. 8: Solar fraction of solar combisystems with 300 liter water storage combined with 5, 10 and 20 m^2 collector area respectively.

5. Summary

In a single family house a solar combisystem with overheat controlled polymer collector in combination with building mass activation can achieve a solar fraction which is comparable with conventional high performing flat plate collector systems coupled only to a water storage.

In solar domestic hot water systems a polymer collector system with thermosiphon cooling can avoid stagnation periods, which allows restarting at any time also after a high insulation period during noon. This gives the potential to reduce the disadvantage of reduced efficiency during operation by longer operation periods in comparison to standard flat plat collectors.

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