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Advantages using inlet stratification devices in solar domestic hot water storage tanks

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Abstract

The thermal performance of a domestic hot water system is strongly affected by whether the storage tank is stratified or not. Thermal stratification can be built up in a solar storage tank if the heated water from the solar collectors enters the tank through an inlet stratifier.

Measured thermal performances of two solar domestic hot water systems are presented. One system is a traditional high flow system with a heat exchanger spiral in the tank. The other system is a low flow system with an external heat exchanger and a newly developed inlet stratifier from EyeCular Technologies ApS installed in the tank. The two systems are otherwise identical which makes it possible to compare the thermal performance and the thermal stratification built up in each tank.

Based on a measuring period of 140 days in the period from April 26, 2016 to September 25, 2016, the investigation shows, that the system with the stratification device has a higher thermal performance compared to the system with the heat exchanger spiral inside the tank.

The relative performance (defined as the ratio between the net utilized solar energy of the low flow system and the net utilized solar energy of the high flow system), is a function of the solar fraction. The lower the solar fraction is, the higher the relative performance will be. Weekly relative performances up to about 1.10 are measured. That is, weekly extra thermal performances of up to 10% are measured for the system with the inlet stratifier.

Keywords: Solar domestic hot water system, thermal performance, thermal stratification, measurements.

1. Introduction

1.1. Background

The heat from solar collectors is, in most marketed solar domestic hot water (SDHW) systems, transferred to the hot water tank in such a way, that the entire tank is heated to a uniform temperature since hot water tanks with built in heat exchanger spirals are typically used as solar tanks. The lack of thermal stratification in the hot water tank can result in up to a 25 % reduction in the thermal performance of a solar domestic hot water system. Thermal stratification in hot water tanks is therefore important in order to obtain a high thermal performance of the solar domestic hot water systems (Furbo et al 2004, Furbo et al 2005, Andersen et al 2006).

Thermal stratification in a storage tank can be established with a stratification device used to transfer solar heat to the hot water tank (Andersen et al, 2007). Stratification devices can be designed in different ways, for instance rigid pipes with holes, with or without flaps preventing back flow and flexible stratifiers made of fabric or polymer films, with one or more layers (Andersen et al, 2007).

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In this paper investigations of an inlet stratifier from Eyecular Technologies ApS are presented. In 2013 EyeCular Technologies ApS invented a new flexible stratifier with good results both in terms of performance and durability in accelerated long term tests. The stratifier makes use of the pressure difference between the water in the storage tank and the incoming water in the stratifier.

1.2. Side-by-side laboratory tests of small SDHW systems

Two small solar domestic hot water systems are installed side by side in the solar heating test facilities at the Technical University of Denmark (DTU), Lyngby, Denmark. The systems are identical, with the exceptions of the stratification device and the heat exchanger methods, see Fig. 1.

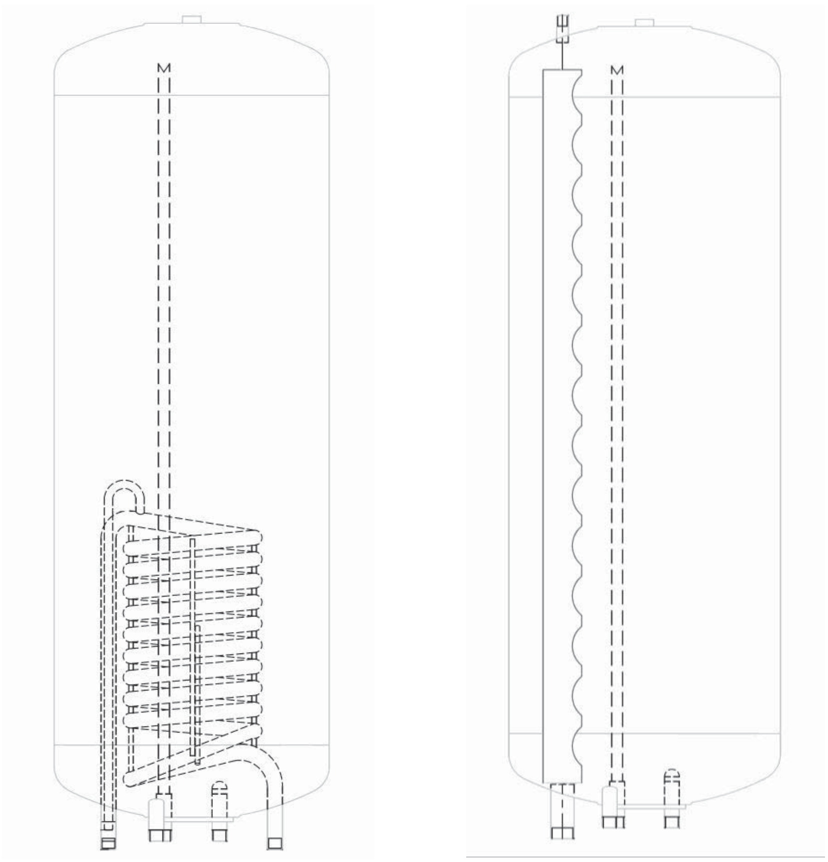

Fig. 1: Sketches of the two tanks in the SDHW systems.

The solar collectors for each system have an aperture area of 2.36 m², see Fig. 2. The solar collectors are facing south with a tilt of 45°. The data of the collectors are given in table 1.

Tab. 1: Data for solar collectors used in the two SDHW systems

Collector type	TLP ACR 2600, Hewalex, Poland
Maximum efficiency	0.827
First order heat loss coefficient	3.247 W/m²K
Second order heat loss coefficient	0.020 W/m²K²
Incidence angle modifier for an incidence angle of 50°	0.94

The daily hot water consumptions for each system is 135 liter heated from 20 °C to 50°C, corresponding to approximately 4.5 kWh. The daily hot water consumption is tapped at 7 am, at noon and at 7 pm in three equal volumes. The tanks, which are produced by METRO THERM A/S, Denmark, have volumes of 255 l, see figure 2.

One of the systems is a typical marketed small solar domestic hot water system with a built in heat exchanger spiral in the hot water tank.

The other system has an identical tank but without the spiral heat exchanger. This tank is equipped with a polymer film inlet stratifier developed by EyeCular Technologies ApS.

The specific stratifier model applied in the present test is developed for low flow solar combi systems with flows rates from 2 - 4 l/min. If operated at lower flow rates than 2 l/min, the efficiency of this specific stratifier model will, according to the company, decrease due to heat loss from the stratifier. Unfortunately, the company has not yet developed a stratifier for flow rates below 2 l/min, let alone a flow rate of 0.5 l/min.

An optimized low flow system operates at a flow rate of 0.15 – 0.20 l/min/m² solar collector. In the present test, the low flow system should therefore ideally be operating at a flow rate of approx. 0.5 l/min. Higher flow rates than 0.5 l/min will reduce the thermal performance of the system somewhat. Together with the company, a compromising flow rate of 1.0 l/min was decided upon, still knowing, that this flow rate is not ideal for the stratifier nor the system.

The solar heat is transferred from the solar collector fluid to the DHW water through an external flat plate heat exchanger. The heat exchanger has a heat exchange capacity rate of about 150 W/K. The propylene glycol/water mixture used as solar collector fluid in the solar collector loops is a 40% mixture.

Fig. 2 Pictures of the storage tanks and solar collectors in the two SDHW systems.

The high flow system with the heat exchanger spiral has a volume flow rate of 2.5 – 3.0 l/min in the solar collector loop. The low flow system with the stratifier has a volume flow rate of 1.0 l/min, both in the solar collector loop and in the DHW water loop transferring the solar heat to the tank. The upper 95 l of the tanks have the option of being heated to 50.5 °C by means of 3 kW heating elements.

Copper pipes with a total length of 34 m for each system are used in the solar collector loops.

The solar collector loop in the high flow system with the heat exchanger spiral is equipped with a circulation pump having a power consumption of 50 W in order to ensure a flow of about 2.5 – 3.0 l/min throughout the entire test duration. The two circulation pumps on either side of the external heat exchanger in the low flow system with the stratification device, has a power of 36 W and 50 W to ensure a flow rate of 1.0 l/min in both loops.

In both systems the circulation pumps are controlled by differential thermostats based on temperature sensors measuring temperature differences between the outlet from the solar collectors and the bottom of the tanks.

2. Measurements and calculation of performance

The data collected from both systems consist of temperature levels, flow rates and energy readings. Temperatures are measured at the in- and outlet of the solar collectors along with the in- and outlet temperatures from the heat exchanger and from the tank. Also temperatures are measured inside the tank in different levels in order to evaluate the level of thermal stratification build up in each tank.

The thermal performances of the two systems are compared by the net utilized solar energies and the solar fractions. The net utilized solar energy is determined as the energy drawn from the system subtracted the auxiliary energy supply to the tank. The solar fraction is the ratio between the net utilized solar energy and the energy drawn from the system. By subtracting the net utilized solar energy from the solar heat transferred to the hot water tank the heat losses from the tank are given.

Tab. 2: Measured energy quantities for the two SDHW systems in the period 18/4-2016 – 26/9.2016 (Excluding the period 27/6 2016 - 17/7 2016 due to malfunction of measurement system).

Energy quantity	SDHW system with stratification device	SDHW system with heat exchanger spiral
Hot water consumption (kWh)	596	598
Auxiliary energy supply (kWh)	95	109
Net utilized solar energy (kWh)	501	490
Solar fraction (-)	0.84	0.82

The measured quantities for both systems are shown in Tab. 2 for the period from 18/4-2016 to 27/6-2016 and from 17/7-2016 to 25/9-2016. The period from 27/6-2016 to 17/7-2016 is excluded due to measurement malfunction. Measurements are available for 140 days during the summer 2016. In Tab. 2 it is seen that the total hot water consumption from each system is 596-598 kWh, which is approximately 4.3 kWh a day. Also as expected the consumption of auxiliary energy is higher for the high flow system with the heat exchanger spiral compared to the low flow system with the stratification device. This results in a higher net utilized solar energy for the low flow system with the stratification device.

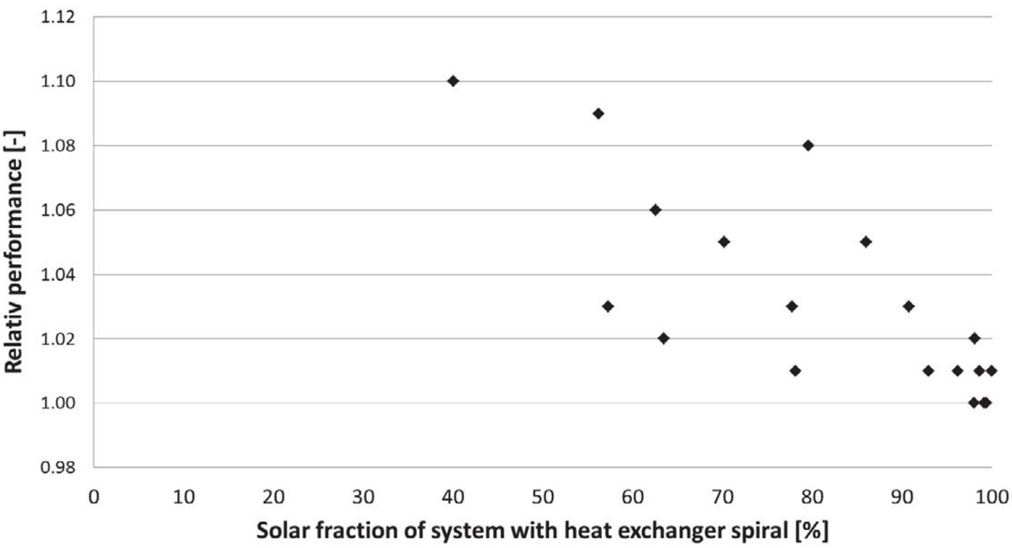

Fig. 3: Weekly relative performance of system with stratification device as function of the weekly solar fraction of the spiral tank system

The 140 days of measurements are divided into 20 periods of 7 days. Weekly relative performances as a function of the solar fraction of the system with the heat exchanger spiral tank are shown in Fig. 3. The relative performance is defined as the ratio between the net utilized solar energy of the system with the stratification device and the net utilized solar energy of the system with the heat exchanger spiral.

Fig. 3 shows as expected that the relative performance increases with a decreasing solar fraction. The measurements show that the thermal performance of the system with the stratification device is up to 10 % higher than the thermal performance of the spiral tank system at solar fractions between 40-50 %.

3. Conclusions

Measurements of thermal performances of two small SDHW systems tested side-by-side under realistic conditions in a laboratory test facility are carried out. One system is a traditional high flow system with a heat exchanger spiral in the tank. The other system is a low flow system with an external heat exchanger and a newly developed inlet stratifier from EyeCular Technologies ApS installed in the tank. The two systems are otherwise identical.

The relative performance defined as the ratio between the net utilized solar energy of the low flow system with the inlet stratifier and the net utilized solar energy of the high flow system with the spiral tank is a function of the solar fraction. The lower the solar fraction is, the higher the relative performance will be. Weekly relative performances up to about 1.10 are measured for solar fractions around 50%. That is, the extra thermal performance is about 10% if the solar fraction is about 50%.

The measurements will be continued during the autumn and winter 2016-2017. It is expected that the extra thermal performance of the system with the stratification device will increase in the winter period with low solar fractions, and that the extra yearly thermal performance will be about 12% if the yearly solar fraction is about 30%.

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