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Flat plate aluminum heat pipe collector with inherently limited stagnation temperature

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Abstract

This paper presents a new flat plate collector technology based on heat pipes. The use of heat pipes can lead to several advantages over direct flow collectors: A simple hydraulic interconnection, an inherently limited stagnation temperature and substitution of copper. This flat plate collector prototype with aluminum heat pipes features all three aspects in one collector. The paper outlines the theoretical modeling approaches and presents the construction of the collector as well as detailed results of measurements of the collector performance. By use of specially designed heat pipes the heat transfer is limited at higher temperatures, which leads to a maximum stagnation temperature of 140°C at the manifold of the collector, thus preventing damages to the solar circuit fluid and solar components. Therefore, cost savings regarding the collector by substituting copper with aluminum and cost savings regarding the solar system due to lowered stagnation temperatures can be achieved.

Keywords: flat plate collector; heat pipe; stagnation; aluminum; copper substitution

1. Introduction

Heat pipes are commonly used in vacuum tube collectors and may lead to several advantages in comparison to direct flow collectors such as simpler hydraulic interconnection, lower stagnation temperatures and even the substitution of copper. However, commercially available heat pipe solutions for collectors are designed fairly similar

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– copper heat pipes with water as working fluid – and the theoretical modeling and optimization is still not thoroughly exploited. On the one hand the paper outlines a newly developed set of theoretical tools for dimensioning and optimization of heat pipes for the use in thermal collectors. On the other hand a new flat plate collector technology with aluminum heat pipes is presented, which highlights all of the beforehand mentioned advantages.

2. Theoretical modeling of heat pipe solutions

Heat pipes represent an additional thermal resistance in the gain heat path of the collector, given that they are positioned between the absorber and the solar circuit. Additionally the thermal connection between heat pipes and solar circuit fluid – the manifold – also represents a thermal resistance. For optimization of heat pipes in vacuum tube collectors or analysis of heat pipe solutions for other types of collectors the heat transfer characteristics of both components have to be known.

On the basis of existing empirical models and experimental data, which are determined at ISFH with novel test rigs (as described e.g. in [12]), we developed a new set of equations to fully describe the heat transfer characteristic of heat pipes. For calculation of the thermal resistance of heat pipes the single heat transfer mechanisms need to be considered. Fig. 1 shows an equivalent resistance network of the main influences on the overall thermal resistance of heat pipes.

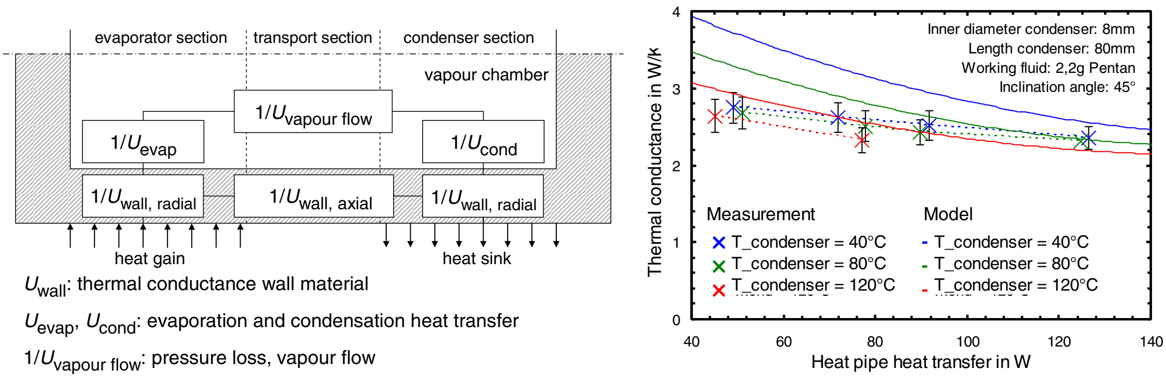

Fig. 1. Equivalent resistance network of the main influences on the overall thermal resistance of heat pipes (right) and exemplary comparison of measured and theoretical modeling of thermal conductance (inverse of thermal resistance) of a heat pipe with Pentan as working fluid (left)

The pressure loss of the vapor flow and the axial heat transfer due to thermal conduction in the heat pipe wall can be neglected since these influences are very small. The radial conduction in the tube wall at the evaporator and condenser of the heat pipe can be calculated by the standard approach for thermal conduction in a hollow cylinder (e.g. [10]). The heat transfer by evaporation and condensation inside heat pipes have been the subject of many publications as for example [1,2,3]. Comparison to own measurements of the thermal resistance of heat pipes for collectors at ISFH shows, that the calculation of the evaporation and condensation heat transfer coefficients in [1] shows the best agreement. [1] is therefore used in our heat pipe model according to Fig. 1.

Regarding heat pipes – besides the thermal resistance – the heat transfer limitations have to be taken into account, too. We found, that for the use of heat pipes in solar collectors only the entrainment limitation and the dry out limitation have to be taken into consideration. Fig. 2 shows, that the entrainment limit occurs at lower operation temperatures. Therefore, the heat pipe has to be designed, so that the entrainment limit does not affect the collector's performance. Fig. 2 shows also, that the dry out limit can be used for lowering stagnation temperature since it occurs at higher operation temperatures.