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Polymeric materials in solar-thermal systems - performance requirements and loads

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Abstract

A major basic problem in selecting appropriate polymeric materials and processing technology routes is related to the lack of well-defined functional and performance requirements on the component level and to material property requirements on the specimen level.
Hence, in a first step several reference climate regions were defined for pumped systems (continental (Graz/Austria), moderate climate (Beijing/China)) and non-pumped systems (Mediterranean (Athens/Greece), hot and dry (Pretoria/South Africa), hot and humid (Fortaleza/Brazil)), respectively. For each of these reference regions various solar-thermal plant types (e.g., domestic hot-water systems for single family houses (pumped and thermosiphon); domestic hot-water systems for multi-family houses; solar combi-systems for domestic hot-water and space heating (pumped) were pre-defined and evaluated and optimized virtually by modelling and simulation.
To determine performance requirements on the component level and to derive material property requirements on the specimen level all-purpose modelling and design tools for collectors were implemented and used which allow for the description of temperature profiles, stagnation conditions, efficiency curves, pressure losses, distribution of fluid and heat flow and the thermal and hydraulic optimisation of the whole collector.

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1. Introduction

A crucial aspect of using polymeric materials in solar thermal systems is the exact knowledge about the occurring loads especially for temperature and pressure changes. The limited thermal property in various polymers in comparison to the present primarily used materials (copper, aluminum or glass) in reference systems makes it

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inevitable to determine load profiles. In the framework of the Austrian project SolPol investigations were made to create temperature and pressure load matrices for the main components of solar thermal systems. To achieve a broad knowledge-base, different applications (domestic hot water in single and multifamily houses, combi-systems) and systems concepts for the main climate zones of the world have been investigated. Furthermore, modified polymeric solar thermal systems with overheat protection (backcooling, ventilation, thermotropic layer) and without overheat protection (drain-back, thermosiphon) have been examined. Extended simulations have formed the basis to deliver load profiles for solar thermal systems based on polymeric materials. This paper gives an overview over the performance requirements for the materials.

2. Reference sites and applications

Five reference sites with existing potential and intensified solar thermal market activities have been identified to generate a wide range of system loads as a result of different climate conditions: continental, mediterranean, hot and dry, tropical and moderate. The dimensioning of the reference systems was determined by the collector area which is in line with the specific market standards and the climate conditions (see Table 1).

Table 1. Summary of the climatic conditions at the selected locations; applications as well as the dimensions of the reference solar thermal systems (gross collector area) correspond to the chosen site; DHW…domestic hot water, SFH…single-family house, MFH…multi-family house.

	climatic conditions			gross collector area [m²]			
site / climatic zone	accumulated global radiation (horizontal) [kWh/m²a]	ambient temperature min [°C]	ambient temperature max [°C]	DHW-SFH, pumped	DHW-SFH, thermo siphon	Combi-System-SFH, pumped	DHW-MFH, pumped
Central Europe (Graz) / continental	1160	-12	33	6,6	-	18	44
South Europe (Athen) / mediterranean	1610	2	38	-	3,8	17	42
Africa (Pretoria) / hot, dry	2050	1	34	-	2,5	-	38
Brazil (Fortaleza) / tropical	2030	22	33	-	2,4	-	22
China (Peking) / moderate	1480	-14	38	-	4	18	50

3. Thermal loads in an overall system

Determination of load profiles prerequisites an overall consideration of the whole solar thermal system. For this purpose the reference systems were built up and simulated with the simulation programs Polysun [5] and SHW [2]. Figure 1 shows the temperature load profiles from different system components derived from a typical reference system in Graz (Austria) as a representative location in Central Europe. The solar thermal system provides domestic hot water and supports space heating. The temperature in the energy storage tank is limited to a maximum value of about 90 °C by the controller.

Especially during summer month, temperatures above 200 °C can be reached at the surface of a selective coated absorber in the state of system stagnation. This implies that several technological challenges have to be met prior to the use of polymeric materials in solar thermal systems. This includes active overheat protection (backcooling, ventilation, thermotropic switching) and passive overheat protection (thermosiphon systems) for commodity plastics as well as “drain-back” solutions for engineering and high performance polymers.